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PROCEEDINGS OF THE NINTH ANNUAL NATIONAL CONFERENCE OF AIIE

June 12-13, 1958, Los Angeles, California

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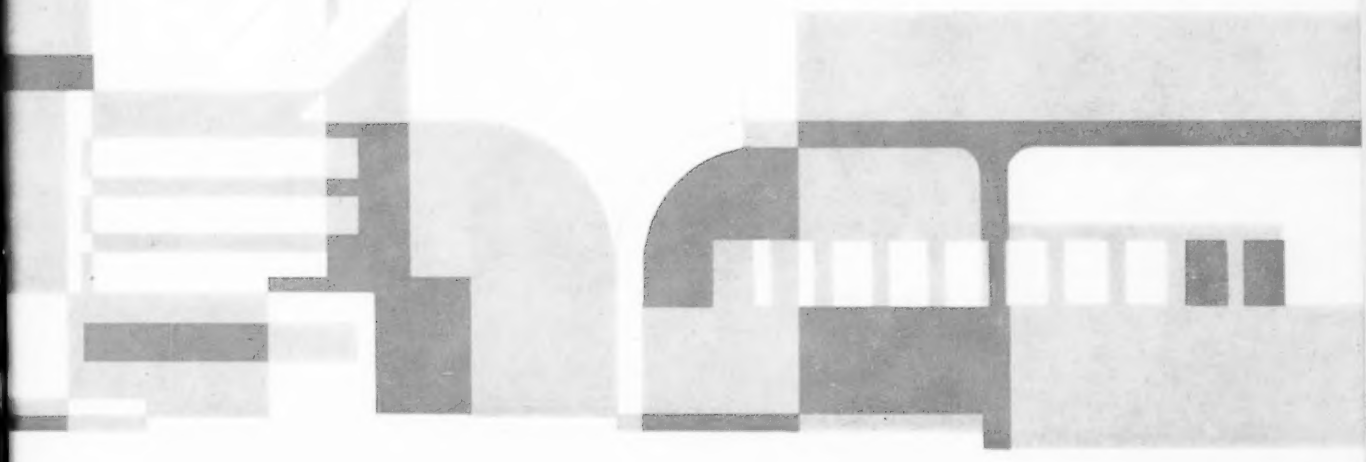

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Highlights of the Ninth Annual National Conference

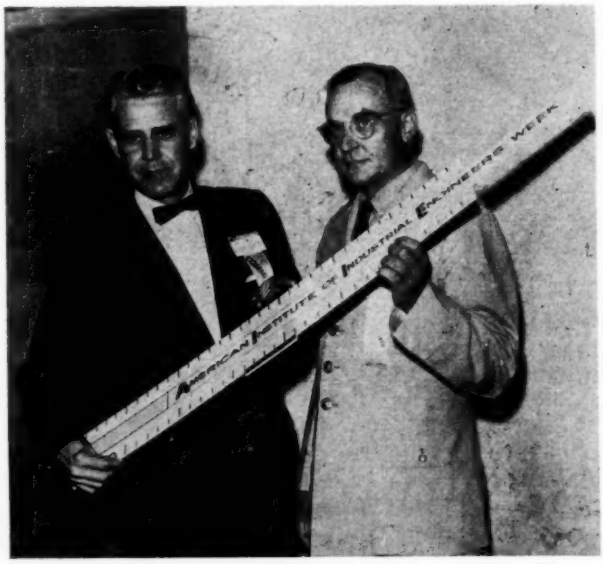
by **HOWARD M. DICKASON**

Branch Manager, Anderson-Nichols & Company, Los Angeles

ANOTHER successful National AIIE Conference, the "Ninth," is now history. The scene was the beautiful Statler Hilton Hotel in Los Angeles, California, and the dates were June 12, 13, and 14, 1958.

This is a first for the West Coast, since previous National Conferences have been held either in the Midwest or East. But despite the distance from our nations center of population, a large number of persons made the trip, bringing total attendance to more than 600. The excellent turn-out once again attests to the nationwide interest in the youngest and fastest growing of professional engineering organizations.

Simultaneous sessions were so arranged that registrants had several choices of subjects. Speakers were selected to provide balance between manufacturing, processing and service industry.



GENERAL CONFERENCE CHAIRMAN, HOWARD M. DICKASON, of Anderson-Nichols & Company, left, and GENERAL THURMAN, Director for Procurement and Production *Air Materiel Command*, Wright Field, Dayton, Ohio, who gave the keynote address. demonstrate the theme "American Institute of Industrial Engineers Week," as proclaimed by Mayor Poulson of Los Angeles.

INDUSTRIAL ENGINEERING—GATEWAY TO PRODUCTIVITY

The theme carried out during the Conference was "Industrial Engineering—Gateway to Productivity." It was built around an invitation "to step through the gates to tomorrow's advancements in new ideas, new techniques and new equipment; for the Industrial Engineer does, indeed, hold the key to increased productivity demanded by business today. Because he must be alert to the challenge of his profession, he must be alive to the trends in the mathematical, physical and social sciences, and he must realize that only through interchange of knowledge can the individual keep pace and continually improve his position and earning power."

To this purpose the Ninth Annual AIIE Conference was dedicated. A wide range of subjects, of vital interest to large and small operations alike, was discussed by qualified and working authorities in each field . . . productivity in manufacturing, processing and service industries . . . administration of industrial engineering projects . . . product design, facilities utilization and planning, economic analysis of automatic production equipment, investment principles and profit control . . . mathematical techniques of analysis . . . use of latest computing machines . . . advanced industrial engineering methodology . . . psychology . . . human engineering.

Our roster of some 50 speakers was comprised of eminently qualified men who know the theories and application of industrial engineering techniques in industry, education and government. Manuscripts of their speeches constitutes this special issue of Conference proceedings.

GENERAL SESSIONS

The Conference was opened with a keynote address on Thursday, June 12, by General Thurman, Director for Procurement and Production *Air Materiel Command*, Wright Field, Dayton, Ohio.

Simultaneous sessions followed the keynote address and were scheduled so that Conference attendees could choose between talks of representatives from manufacturing, processing and service industries. Manufacturing was represented by speakers from electronic, aircraft and light manufacturing. Processing speakers had backgrounds in petroleum, steel and food, while the Services industries included insurance, transportation and retail trade.

The luncheon meeting was addressed by Charles Luckman, former president of Lever Bros. and now a partner in the Architectural Engineering firm of Pereira and Luckman, on the subject of "Human Engineering."

Afternoon sessions covered many subjects such as Product Design, Product Development, Facilities Utilization and Planning, Factors in the Economic Analysis of Automatic Equipment, The Technique of Profit Control, Organization Analysis, Productivity Demonstrated—A Case Study of Industrial Engineering in Action and Linear Programming—Planning for Optimum Productivity.

A reception for national officers was held at the close of the first day's technical talks. A banquet for registrants and their wives followed. Featured speaker was Dr. Neil H. Jacoby who talked on "Some Economic Aspects of the Cold War." A lively question and answer session followed.

The second day's program on Friday, June 13, was equally well attended. Technical subjects covered in the morning were: Monte Carlo Methods; Simulation-Game Theory of the Firm; Some Practical Simulations of Operations; Automatic Production Recording; Automatic Production Control; Computerized Production Control; Experience in Multiplying Defense Capabilities through Data Processing; Experience in Utilizing Computers; the Impact of EDPM on Jobs, Procedures and People; Production Purchasing and Inventory Controls; Working Capital, Replacement Capital and Expansion Capital for Small Plants; Small Plant Sales and Contracts; and Psychology and Productivity.

Friday's luncheon speaker was Dr. Robert S. Bell, President of Packard-Bell Electronics Corp., whose topic was "Motivating Engineers."

In the afternoon technical sessions continued on the subjects of "Management of New Products"; Job Simplification vs. Job Enlargement; Productivity Without Compromise; Industrial Engineering vs. the Burden of the Past; Productivity through attention to Quality and Human Implication of Productivity—the Social Responsibilities of Industrial Engineering.

LADIES TOUR

A ladies tour was arranged for both days of the Conference. Wives of Conference registrants were taken by bus to many points of interest in the Los Angeles area.

The first day's tour took in the sights of Hollywood, Art Linkletter's Houseparty telecast, lunch at Farmers' Market, homes of movie stars in Beverly Hills, and a trip through Metro-Goldwyn-Mayer Studios.

The second day's tour took in some of the sights of historical interest in Los Angeles: Forest Lawn, the Rose Bowl, Pasadena Playhouse, Descanso Gardens, Huntington Library and Art Gallery, and the San Gabriel Mission.

The tours were well attended and comments were unanimous in approval of the program and the way in which it was handled.

TOP MANAGEMENT DECISION GAME

One of the highlights of the Conference was the Top Management Decision Game in which 40 presidents and top executives of southern California business participated. The Young Presidents' Organization of Southern California furnished 20 of its members for the first day of play. Top executives were selected from Conference registrants for the second day. This is management's most dramatic device for training top executive personnel to become "generalists." Played on an IBM 650 computer by five teams of four players each, the assumption is that the five companies are manufacturing the same product for the same market. Sales and profits are determined by the competitive interplay of decisions as to pricing and allocation of corporate funds made by the teams of players. Eight decisions are made after analyzing each "quarterly" statement. After all decisions of the competing teams are in, they are fed into the IBM 650 computer by punched cards. The computer feeds back the consequences of the decisions and how they affected the new competitive relationship of the five teams or companies. Several years of decision making were condensed into each day of play using this electronic device.

Closed circuit television was provided in order that any Conference attendees desiring to could observe the Game play.

CHIEF INDUSTRIAL ENGINEER'S FORUM

A Chief Industrial Engineer's Forum was held in three parts. Each was dedicated to ways and means of operating the Industrial Engineering Department at maximum efficiency. Modern systems to control costs and effectiveness of the Industrial Engineering function were outlined by top level representatives of major companies.

The first part "Central Organization and Control" was handled by Richard Forberg, Director of Industrial Engineering, Procter and Gamble, followed by P. S. Willard, who spoke on Factory Organization and Application.

The second part dealt with assignment of work, the formation of teams, selection of projects, budgeting procedures, degree of functional specialization, etc. Speakers were: George H. Gustat, Director, Industrial Engineering Division, Eastman Kodak Co.; Warren Alberts, Vice President, Industrial Engineering, United Airlines; and Douglas Watson, Principal, McKinsey & Co.

These sessions were extremely well attended.

IN-PLANT VISITS

Another special feature of the Conference was In-Plant Visits. Tours were made of some of southern California's most progressive companies. On-the-spot observations and discussions were made of especially noteworthy application of Industrial Engineering techniques.

Richfield Oil Co. was host to one group and provided a fresh and unique approach to clerical work measurement and work standards. Pacific Mutual Life Insurance Company demonstrated innovations in the use of electronic data processing equipment and displayed the com-

pany's Univac installation. General Petroleum Corporation showed methods used in the control of systems, machines, maintenance schedules and demonstrated the company's Datatron 205 computer. Southern California Edison Company held a panel discussion on the problem of plant site selection and development.

EXHIBITS

The Assembly room was filled with 22 exhibits of products and services of interest to Conference attendees. Featured were the latest in business and office machines, pre-determined elemental time data systems, records retirement systems, as well as displays by local universities, publishing companies and chambers of commerce.

THE CONVENTION

The Ninth Annual Convention for delegates and other members was held in the Pacific Ballroom on Saturday morning, June 14. Presiding was outgoing National AIIE President, Gordon Carson, Vice President, Business and Finance of The Ohio State University. President Carson skillfully disposed of all business matters on the agenda within the scheduled time.

At the close of the Convention, luncheon was served in the Sierra Room. After luncheon President Carson turned the reigns of AIIE over to incoming President, George Gustat, Director of Industrial Engineering, Eastman Kodak Co. Mr. Gustat reviewed the history of industrial engineering and the contributions it can make to society through such a Professional organization as AIIE.

ACKNOWLEDGMENTS*

The following people gave much time and effort to help make this Conference a success: Howard M. Dickason of Anderson-Nichols & Company, General Chairman; Peter P. Pruce of Ernst & Ernst, Internal co-chairman; C. Wilson Whitson of Markets Unlimited, External Co-chairman; Arnold A. Cowan of Bobrick Manufacturing Company, Conference Advisor; James C. Hiller of Columbia-Geneva Division of U. S. Steel, Director for Arrangements; Harry J. Kraig of Ernst & Ernst, Director for Exhibits; Walter R. Herbst of Consolidated Western Steel Division of U. S. Steel, Director for Finance; L. Roger Grimes of O'Keefe & Merritt, Director for Planning Services; Herbert J. Groelinger of Systems Development Corporation, Director for Program; Robert W. Lockwood of California Bank, Director for Proceedings; Stanley T. Wolfberg of Benjamin Borchardt & Associates, Director for Publicity; John C. Narber of Pereira & Luckman, Director for Receptions; Fred T. Westberg of Autonetics Division of North American Aviation, Director for Registration; and Donald L. Mihelich of Bobrick Manufacturing Company, Director for Special Events.

* Editor's insertion.

Human Relations in Industrial Research Management

ROBERT TEVIOT LIVINGSTON and STANLEY H. MILBERG, Editors

This study provides a sound basis for locating human relations within the total managerial problem of designing and operating the modern industrial research organization. Based on proceedings of Industrial Research Conferences, twenty-seven papers, with integrating introductions, consider human aspects of organized research. "The editors should be commended both for the selection and arrangement of the papers in this collection and for the fluent integration of these papers, which is made possible by their excellent introductions. This book is recommended to anyone interested in the fields of research, sociology, research management, or personnel administration."—*Public Personnel Review.*

$8.50

Effecting Change in Large Organizations

ELI GINZBERG and EWING W. REILLEY

A pioneering investigation into the problems encountered when a large organization, business or nonprofit, seeks to alter its basic structure in order to improve operations. Using case materials from corporate and governmental experience, the authors develop a framework for the systematic study of group behavior under conditions of directed change. They use social science and psychological theory to illuminate the basic facets of directed change. The authors were assisted by Douglas W. Bray and John L. Herma. "A timely, clear and well-written contribution to management understanding."—*Labor Law Journal.*

$3.50

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Gateway to Productivity

by **WILLIAM T. THURMAN,** ***Major General, USAF***

Deputy Director for Procurement and Production, Air Materiel Command

YOUR convention keynote is "Gateway to Productivity." Nothing could be more appropriate for me to discuss with you this morning, since we are now beginning to produce, in limited quantities, the weapons of tomorrow. And nothing could be more appropriate than to talk about the role which you, as Industrial Engineers, have played and should continue to play in our program for today, tomorrow, and the day after tomorrow.

I should like then, to discuss first, the international challenge which faces all of us; secondly, the Industrial Engineer's part and responsibility in this challenge; third, the present status of our ballistic missiles program; and finally, how you can aid us in accomplishing our objective.

OUR CHALLENGE

Today, our nation is at a crossroads. The period through which we are passing is the most challenging one our country has ever faced. Our actions as a nation must be those of a man with broadest vision in the fields of economics, management, education and the sciences. The time is one of brutal self-appraisal. We must determine where we stand and how our resources are being used. Then we must deliberately choose the best possible path to follow as we progress into the missile/space age. The decision must be right the first time. There may not be an opportunity for course correction later on.

The crucial question to us, in the Air Force, is: How can we meet this challenge in using, to the best advantage, our combined resources? In a final sense, and very briefly, the real objective of the Air Force is the employment of air power in the best national interest. With equal brevity, I can say that the Air Force can do this job today, in all its variations.

We must contribute the primary force to the total U.S. effort to deter general war. We must also provide for the air defense of the United States. This means that we must know the possible threat, assess it realistically, and help achieve so strong a posture as to deter the attempted application of enemy power against our country.

The military posture of the Soviet Union is a clear example of dedication to the development of overwhelming force. They have a large nuclear capacity, modern and effective, backed up by sizable conventional forces. They can mount a two-sided offense in peace time. Their nuclear striking power can be used for atomic blackmail. Communist Bloc conventional forces can be used as political pawns in lesser conflicts. And, even while propagandizing against the use of nuclear weapons, the Soviet Union retains a general war capability in nuclear striking power and declines to join in genuine steps designed to reduce that power on both sides under adequate safeguards.

This attitude and capability leave the threat of general war a very real one. That is why we must continue to be prepared, at all times, and under all circumstances, to deter any aggression and, if necessary, to strike back when attacked.

The Air Force is dedicated to deterring war. We see this as a savage uphill battle. It is a day-in, year-out struggle to maintain a deterrent posture in pace with new techniques and developments.

Our actions are based upon big dreams, in the largest sense. Should we fail to recognize this challenge, our nation will eventually lose its economic, scientific and military leadership in the world. Our gross national product must be increased at a rapid rate. To preserve the peace for a golden age, we must think big and act big!

INDUSTRIAL ENGINEERS' RESPONSIBILITIES

I know, and you know, that the future of our nation depends upon each and every one of us. But I also know and believe that leadership in this struggle for survival must come from professional groups such as yours. This may be difficult for you, as individuals, to see and understand on a day-to-day basis, but, today, more than ever before, we must depend upon the creative minds and abilities of our engineers. This is why I feel that this group, which is interested in maximizing the effective utilization of our resources, can have a profound influence on our nation's future.

All of you must recognize that, if this nation is to be great, we must be motivated by a vision of greater things and a greater America. This is an individual problem, and it is only within the minds of each of you that we can provide the flame as well as some of the fuel which will enable our nation to continue as a leader in the free world. As engineers, you are interested in using nature's resources to man's betterment. We, in the military, are interested in using nature's resources to provide a highest qualitative type operational combat weapon. Further than that, we now can see how these weapons which we

have created as a matter of defense and survival, may soon become a means to move man in space and even beyond. Limitless opportunities present themselves.

I think you will agree with me that our challenge today, and our challenge for the future, is just as exciting as that when the steamboat was invented, or when we were opening up the West and developing our own country.

FOUR M'S

You, as Industrial Engineers, are thoroughly familiar with the "Four M's" of the engineering schoolbooks—Men, Money, Materials and Machinery. If you apply these terms to time compressions, as I am sure you have done many times in your daily tasks, you have in a nutshell, our biggest problem in the Air Force today. A little later, I will attempt to point out some of the things we have done in our ballistic missiles program in the respect to the time-honored "Four M's."

The concept of a third World War, if it should ever come, will be altogether different from anything we have seen in previous conflicts. I believe that such a war will be decided within the first thirty days. If we are prepared to fight this war in such a short time span, we will have little to fear. But if we lag behind in our preparedness, we will probably never get a second chance to recuperate and strike back, once we have suffered the initial loss.

Quality, then, rather than quantity, must be our watchword for the future. I doubt that we will ever see again the production lines and stockpiling of World War II and the Korean conflict. In the missile age, we cannot afford such things. Once a ballistic missile is launched, there is no way of retrieving it. And if the slightest mechanical failure occurs in the missile, its mission immediately becomes a total loss.

With the ever-increasing complexity of our scientific and technological developments, we can no longer afford to have many replacement and spare parts in stock for our missiles. These same parts, which we are producing today, may be obsolete by the time the missile is ready to be launched. That is why we must continuously strive for newer and better methods and technologies, for improved materials and equipment.

Let me get back to the first of the "Four M's" for a moment. Best utilization of our existing manpower, with a minimum waste of time, is an absolute prerequisite for the successful completion of our mission. Better organization and management of weapons systems is our continuous goal.

BALLISTIC MISSILES PROGRAM

One major step in this direction, of course, is the Air Force-adopted weapon system concept of procurement. By making one contractor responsible for an entire weapon system, such as the B-58, for example, and by delegating to him the authority to subcontract for the items he does not manufacture, we have, in effect, extended Air Force procurement actions right into the industries involved. Thus, we have compressed time and manpower.

A slightly different concept has been applied to ballistic missile production. Associate prime contractors have been selected to develop and produce the propulsion system, the guidance, and the nose cone. A fourth group of contractors, manufacturing the airframe, also has the responsibility for flight testing and for the integration of the separate systems, making minor modifications for compatibility. All four major contractor groups are responsible for designing and producing ground handling equipment and support equipment peculiar to their systems.

MANAGEMENT

Management of the Ballistic Missiles Program of the Air Force is a streamlined process. Here, more than ever before, we realized the importance of time. No longer could we afford the traditional 8 to 10 years development-to-production cycle. To reduce this time cycle, from theory to reality, we decided to attack all areas of our assignment, concurrently developing the weapons, building a production base, and starting in the operational areas of training and base construction. In short, we took the calculated risk of planning, programming and spending our funds, concurrently, on research, development, testing, manpower training, and other phases of our program.

In order to execute such a program, we had to create a unique management organization, employing simultaneously three major Air Commands, and an industrial concern experienced in the technical know-how.

MONEY

The second "M" you learned about in school is "Money." In the last couple of years our budget for ballistic missiles has more than doubled, and we expect this trend to continue in the future. Today, we are spending at an annual rate of more than 1.3 billion dollars for the airframes, engines, guidance systems, nose cones, and many other supporting components which will eventually result in an operational ballistic missile weapon system. Translated into daily operations, this means that the Ballistic Missiles Program of the Air Force costs us three million dollars every day of the year!

This money is distributed to some 15 major prime contractors, who are building the major systems for us. In addition, we have some 60 secondary primes, who conduct research studies, develop new fuels, design smaller subsystems, etc.

A large percentage of the money which we allot to our prime contractors is, in turn, subcontracted to large and small companies all over the country. This policy of subcontracting is in full accord with our Air Force policy of maximum utilization of the industrial base of our country. In fact, we have always encouraged our large prime

contractors to establish and maintain an economically sound subcontracting structure, making fullest possible use of the many existing small business concerns all over the country. All of our ballistic missile prime contracts now carry a clause which urges the prime contractor to subcontract to small business concerns to the maximum degree possible.

MATERIALS

The third "M" in your engineering cycle stands for "Materials." Here again it becomes obvious that we cannot stand still, and rely on old, proven methods and materials. The introduction and application of the more exotic materials, such as titanium, beryllium, and the likes, in all phases of our programs, are ample proof of the rapid progress we have made. The very nature of heretofore unknown subsystems and components, such as all-inertial guidance, nuclear warheads, solid fuel missile propulsion units, make it mandatory that we devise and develop new and improved manufacturing methods almost every day.

MACHINERY

The fourth, but to us certainly not the last, "M" is "Machinery." This is where our ballistic missiles program has made advances and progress in an extremely short period of time. The Ballistic Missile has placed upon us the responsibility to build entirely new plants and test facilities, produce complicated machine tools, and devise complex laboratory and test equipment. Air Force and industry alike have participated in this undertaking. I am glad to report that industry has done a commendable job in this area. Today, we have in being such new facilities in the amount of more than 320 million dollars. Contractors have spent some 125 million dollars of their own money, while the Air Force has invested more than 195 million dollars. If you consider that today we have eight entirely new plants, and as many new test facilities which were not even in the planning stage at the outset of our program in 1954, I am sure you will agree that we have "compressed time" to the fullest degree possible here.

ACCOMPLISHMENTS OF BALLISTIC MISSILES PROGRAM

Permit me, now, to give you a few milestones of our ballistic missiles program which should give you an idea of what we have accomplished, in the short time that our program has been in existence.

The first letter contract for research and development of the THOR Intermediate Ballistic Missile was given to Douglas Aircraft Company in the summer of 1955. Less than twelve months later, we fired our first missile from Cape Canaveral. We know now that the first operational THOR squadron will be deployed overseas by the end of this year.

At the same time, we were preparing our ground equipment and logistical support structure. Also, at the same time, we were constructing facililities for our missile training base at Cooke Air Force Base, some 200 miles north of here, and are now getting underway at another base near Cheyenne, Wyoming.

In June of last year, slightly less than three years after the establishment of our management concept, the first ATLAS test vehicle was launched from Cape Canaveral. Behind that lay thousands of tests of components, subcomponents, and many hours of testing captive missiles.

In November of last year, we started the development, design, production and testing of a completely new research vehicle. Our objective was to furnish proof of the correctness of Air Force theories of nose cone re-entry. To accomplish this required the conception, engineering, design, building, delivery, support, testing and firing of two entirely new items of hardware. In April of this year, slightly less than five months after inception of this project, the firing was accomplished.

CONCLUSIONS

Automation is one of the basic tools of the Industrial Engineer in compressing time. We, in the Air Force, have used this management tool extensively for many years in giving logistical support to our combat forces. We have depended on automation and electronic data processing in supporting our fighters and bombers. Since missile reliability requirements are many more times stringent than those for manned aircraft, it then becomes obvious that we had to develop entirely new techniques of management and automation to take care of these requirements.

It has taken us less than two years to create a new logistics support system for ballistic missiles. Once this system is fully tested and operating, it could easily supplant our old logistics system.

We are using electronic data processing to the fullest extent possible in this task. At our Air Depot at San Bernardino, California, we now have in operation a huge IBM 705 computer. This computer will keep tabs on missile components from the time they are ordered from contractors until they are installed in the operational units. This huge electronic brain will keep a watchful eye on the more than 100,000 parts needed to keep the missile in preparedness at widely scattered launching sites. It will be able to solve management problems in the areas of supply, maintenance, transportation, and quality control. The system will connect the Ballistic Missiles Manager, the operating squadrons, the supporting bases, and the contractors, in order to effect necessary action with a minimum lag of time. It is too early to tell the saving in money and manpower, but these savings well exceed hundreds of times the actual cost of the system.

It has been less than four years since we were given our big challenge. We feel that we have been essentially on schedule in meeting our milestones. And, barring unforeseen circumstances beyond our control, we do not antici-

pate any serious slippages in the future. Individually and collectively, you have helped us in achieving our present status.

But we cannot afford to relax and rest on our laurels. The period of severe transition through which we are now passing has created a new set of problems for all of us. As our share of the problems, we, in the Air Force, must answer such pressing questions as what is the best development program for long-range war deterrent power, and the best organizational structure for operating our weapon systems on hand and procuring and producing superior ones for the future.

For your part, you, as Industrial Engineers, and as members of American industry, must keep pace with current technology; project yourselves into the immediate future so that production of high performance weapon systems can continue unabated; and press to an early successful solution of the hardware problems related to space operations.

Together we must project our current level of cooperation into the years ahead. Using experience as a springboard, we should be able to assure this nation a defense establishment that will become progressively stronger as we push through the aircraft-missile-space age.

This is the challenge for all of us. I know we can meet this challenge—for we have no other choice.

Chief Industrial Engineers' Forum

Central Organization and Control

by **RICHARD A. FORBERG**

Director, Industrial Engineering Division, The Procter & Gamble Company, Cincinnati

YOU are all aware how much the nature of a business influences its organizational form. I think it is important that we should start today by describing briefly the nature of the products and processes of The Procter & Gamble Company. Our products, for the most part, are packaged consumer goods. These range from the soaps and synthetic detergents with which you quickly associate us, through liquid bleach, shampoos and dentrifices, deodorants and home permanent wave kits, to tissue paper products, shortening, and cake mixes. Some of our products go to industrial users—cellulose pulp, glycerine, fatty acids, and many industrial variations of our consumer products.

It doesn't stretch your imaginations to perceive that these products are produced using chemical processing systems and are packed on highly mechanized packing equipment.

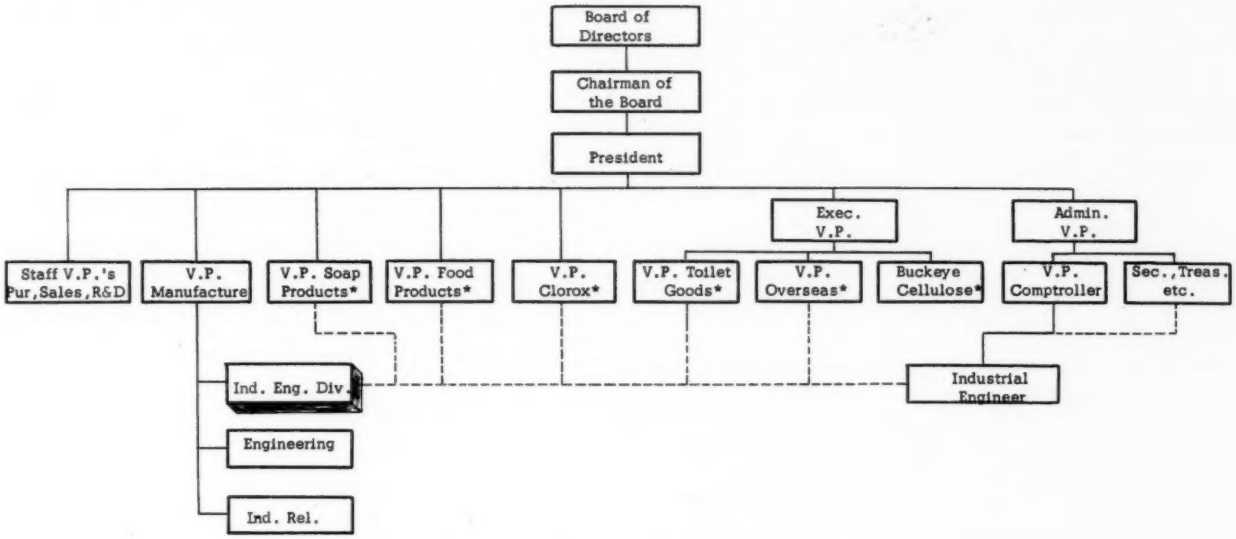
This is a large volume business with current annual sales of 1.1 billion dollars. Most of the homes in America use one or more of our products. Since product unit costs are low, and materials are generally available, our plants are located in the centers of population across the country. We have foreign operations in Europe, Central and South America, and Asia. In all there are 64 manufacturing plants.

CORPORATE ORGANIZATION STRUCTURE

The corporate organization to carry on this business has been going through the process of divisionalization in response to the demands of growth. Separate operating divisions have been created for product groups. These operating divisions have profit responsibility but are also required to conform to broad corporate policies as established by staff Vice Presidents in each of the functional areas of Sales, Advertising, Manufacturing, and Research and Development.

This corporate organizational form is illustrated in Figure 1. The positions of the various Industrial Engineering organizations are shown. The organizational group which I represent, is the Industrial Engineering Division. It is one of the Technical Staff Divisions reporting to the Vice President—Manufacture, as shown in Figure 2. The Technical Staff Divisions also include Industrial Relations, Engineering, and Engineering Exploration. The Industrial Engineering Division is a lineal descendant of our first Industrial Engineering organization which came into being thirty years ago. The function was begun and developed by the late Stewart M. Lowry, who is known to many of you for his collaboration on an early text on time and motion study, and who later was a west coast principal for Booz, Allen and Hamilton. This Central Industrial Engineering Division has been instrumental in helping to establish plant Industrial Engineering Departments.

The successful use of Industrial Engineering by manufacturing has prompted the introduction of similar staff functions into the commercial side of the business—Buying, Traffic, Sales, and Advertising. You will note that we show an Industrial Engineer reporting to the Vice President and Comptroller. This position was recently established to coordinate these activities. It might be noted in passing that we use Industrial Engineering concepts and



*Indicates Industrial Engineering organization operating at the plant level.

FIG. 1. Simplified Organization Chart

techniques in the Production Engineering and Field Construction activities of the Engineering Division.

INDUSTRIAL ENGINEERING OBJECTIVES

Before I talk further about organization, and the reasons for the particular forms which we use, I think it would be well to discuss our concept of the Industrial Engineering function. First, what are the objectives of Industrial Engineering; and second, what functions do we carry out in pursuit of these objectives?

1. Our first objective, as we see it, is that the design of the job and the industrial environment recognize the needs and capacities of men. I put this first because I believe that is where it ought to be. As a management we have a history of maintaining exceptionally good relations with our people. As partial tangible evidence of this concern was the introduction of Profit Sharing in 1885 and of the Guarantee of Annual Employment in 1923. Other groups have design responsibilities that bear on this objective also. Some of you from backgrounds other than chemical process may need explanation of that point. In a business such as ours, Research and Development (i.e. Chemical Engineering) has design responsibility for product and process. The Engineering Division has design responsibility for process equipment, services, and structures. The line organization of manufacturing is very much involved as the user, and contributes to design decisions, as do the medical and safety groups of the Industrial Relations Division. The effective collaboration of all these groups is necessary for attaining our first objective. With start-up and operation, this is a continuing responsibility.
2. The second objective of Industrial Engineering is to assist the line and other staff in finding and evaluating ways to reduce costs by changing methods and materials, while maintaining or improving quality and job satisfaction. This is our hunting license to question anything and everything. In our thinking, we consider the cost horizon to extend from the suppliers' operations to our customers' docks.
3. Our third objective is to provide management with information to evaluate and control performance on operating expense and other costs. This means to establish and maintain performance standards and to use these in evaluating performance, for the payment of extra compensation, and for recommending control action.

INDUSTRIAL ENGINEERING FUNCTIONS

These objectives are general and exist for the Industrial Engineering function wherever we find it in the business. Now, let me be somewhat more specific. I'd like to talk next about the functions of the Industrial Engineering Division. Then I intend to go on and tell you how we are organized to carry out these functions.

You will remember that we have a Central Industrial Engineering Division, one of the Technical Staff Divisions, reporting to the Vice President—Manufacture and this Vice President has a policy-making responsibility for all manufacturing operations.

1. Our first function, then, is to design policies, plans, and procedures, to accomplish our objectives, and propose these for authorization. Most of this activity relates to work measurement, wage incentives, cost control, and supervisory bonus. In connection with this function, we may need to do research and development work preliminary to design. Associated with this function is our concern to keep up with the best concepts and practice in our field outside the Company.
2. Our second function is to promote the uniform administration in the plants of the approved plans and policies. With this function, we must observe and report the quality of administration practiced by plant line and staff. Auditing for adherence to Company policy and good practice is regularly scheduled through the plant operations.
3. Most of you recognize the need to sell the potential in

Industrial Engineering in your organizations. Accordingly, one of our functions is to promote justified improvements and extensions of Industrial Engineering practices. Earlier in my remarks, I gave you some indication of the extent of Industrial Engineering coverage in our corporate operations.

4. As a chemical process industry, we have had more "systems" integration than those of you in hard goods manufacturing. We have had to develop design concepts to deal with integrated process, information, and service systems. So today in Industrial Engineering, we consider it a function of ours to do development work on major process, information, or service systems with the objective of cost reduction.
5. We have a responsibility to aid in staffing the growing Industrial Engineering organization. To this end, we recognize that we have the function of hiring, training, and developing men as professional Industrial Engineers and for general management.
6. As any staff group, we also stand ready to advise and assist other divisions of the Company in our area of technical competence, when we are requested.

To this point I have stated the nature of our business, its general organizational form, the positions of the Industrial Engineering organizations in the corporate structure, and the objectives of Industrial Engineering. I have described the functions of the Industrial Engineering Division which is a source of stimulation, development, and control for plant Industrial Engineering activities. Now I intend to describe how the Industrial Engineering Division is organized to carry out these functions. The Industrial Engineering Division consists of some 50-60 people of whom two-thirds are technically trained and the others are non-technical or clerical staff personnel.

ORGANIZATION OF INDUSTRIAL ENGINEERING DIVISION

The Division is divided into five Departments. Figure 3 shows these Departments arranged from left to right, in an order which represents the sequence of addition to the Division. The Incentives and Standards Department has design responsibility for manufacturing expense control, and financial incentive systems. The Department is divided into two Sections. The first Section, Job Study and Incentives, is interested in the problems of the design of work measurement, wage incentive, and supervisory incentive plans. In addition, this group carries out our function of auditing the quality of plant administration in this area. The Cost Control Section is concerned with the design, policy, interpretation, and administration of our Cost Control Plan. This Plan is supplementary to our process cost accounting system. It provides information to departmental management for improved operation, and is the basis for evaluation of operating expense performance. On the basis of this evaluation, we pay plant management, line and staff, added incentive compensation. This Section audits plant administration of cost control.

METHODS DEVELOPMENT DEPARTMENT

It has always been a part of our approach to job standardization to do a justified amount of methods study. However, we recognized more than fifteen years ago that we were not giving sufficient attention to cost reducing methods change. To increase the rate of methods change, we established the Methods Development Department. This group carries on a number of different activities. First, we are interested in the concepts which are held by management people about the possibility, the desirability, the necessity for cost reduction. We have found that we are well justified in devoting time to what might be called "research" in the concepts of cost reduc-

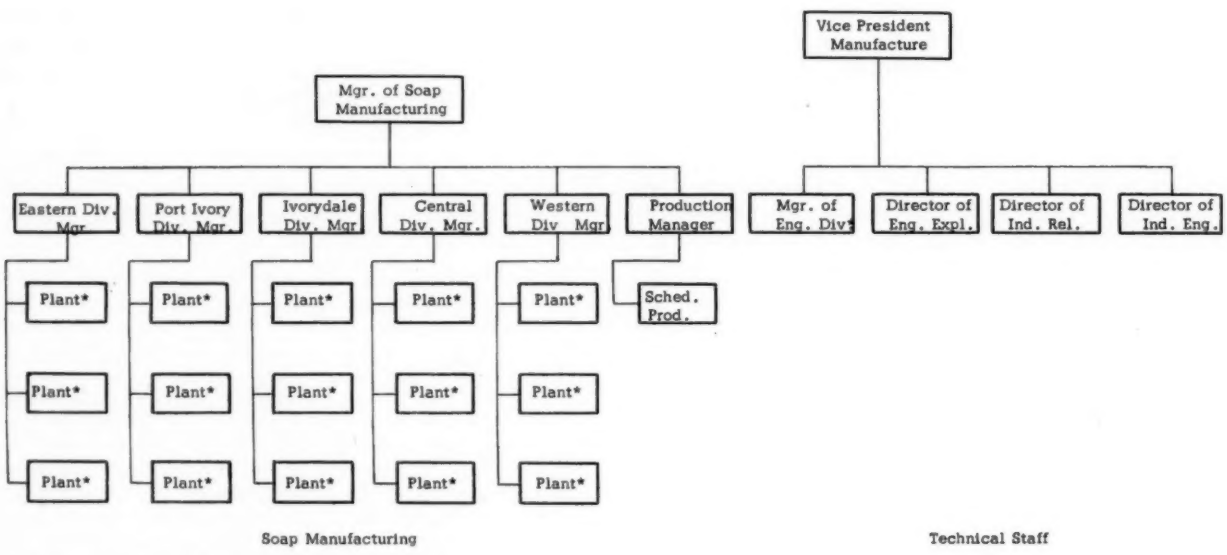


FIG. 2. Simplified Organization Chart

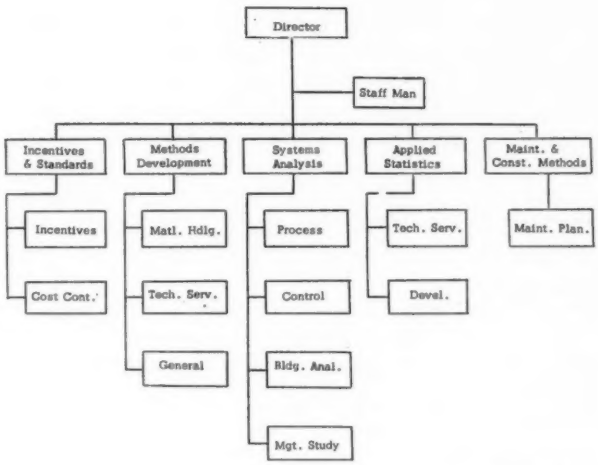


FIG. 3. Industrial Engineering Division Organization Chart

tion. We have been well justified in devoting time to the development of training aids to carry these ideas to our management group and in finding ways to organize more effectively to produce innovation and change. This work, from the beginning, has been a fundamental part of the Methods Development Department's activities.

A logical extension from this is our promotional activity in regard to the plant cost reduction programs. The management groups in the plants are organized into teams. These teams consider possible projects and establish annual cost reduction goals. One of the activities of the Methods Development Department is to find ways of improving this program, interchanging ideas between plants, analyzing successes and failures of organization and administration, and summarizing for management the achievements of the program.

In addition to these more general activities, we carry on specific development projects. Some of these are short range; other relatively long range. In the short range category, for example, is Special Pack Methods Development. A typical Special Pack is a "promotional pack" which offers two bars of Ivory Soap with a carton of Tide. These two products are produced by different processes in different locations in a plant. To combine them into one finished product package by attaching the bars to the carton, requires methods development. It is more efficient to work out the method at one time for the whole Company than to require each plant to solve the problem. Hence, one of the activities of the Methods Development Department is to develop methods for such promotional packs.

There is an important area of our operations where chemical change does not take place and where the level of mechanization is relatively low. This is our Finished Product Warehousing and Shipping activity. The material handling and control systems for these operations have been the primary design responsibility of Industrial Engineering. We have evaluated unit load handling systems and have done development work with the lift truck manufacturers, progressing from fork truck through Pul-Pac to clamp truck operations on our multi-package unit loads. We are now engaged in a major long range effort to evaluate integrated mechanized handling equipment for warehousing and shipping.

SYSTEMS ANALYSIS DEPARTMENT

Closely integrated mechanized systems cannot be designed adequately one component at a time. For existing systems there are cost reduction possibilities which are only realized when the system is considered as a whole and in relation to other activities in the Company. We have found it necessary to supplement the "Job-Analysis Approach," which is characteristic of most Industrial Engineering, with a "Systems-Analysis Approach" to design and cost reduction.

In organizing this Systems-Analysis Approach, we have specialized by system categories. We deal with three types of systems.

1. Process systems are those in which materials flow.
2. Control systems are those in which information flows.
3. Building systems are those structures which house administrative, engineering, and research activities.

You will note on Figure 3 that each Section of the Department is specialized in one of these categories.

A typical project in each Section may give you a better concept of the activity involved.

In the Process Systems Section one man has specialized on our Synthetic Granules Production System. There are similar producing units at each of our US soap plants. The capital investment totals over 100 million dollars. Our efforts have been directed toward:

1. Decreasing downtime.
2. Determining optimum processing cycles.
3. Evaluating differences in operating practice between units and promoting best practice.
4. Helping to establish goals for improved operation.
5. Analyzing training needs.
6. Comparing managerial methods and organizational forms.

The Control Systems Section has concentrated much effort on the Production Scheduling System. We have been able to develop a new system which takes the significant costs into consideration, provides better balance between stocks in inventory, and will enable us to determine optimum inventory levels. Systems for storage space allocation and product distribution have also been investigated. This Section is currently aiding in the design of the mechanized warehouse system by programming the systems simulation studies on the high speed computer.

The Buildings Analysis Section works with the groups who use office and laboratory space. Long range space needs are defined and analyzed. Needs for new building construction are developed. Alternatives are considered to

minimize renovation and new construction costs. Some experimental work is done on office and laboratory furniture and layouts. The design of service facilities (dining rooms, shops, parking lots, and special purpose spaces) receives attention to minimize cost of construction, operation and the problems of future expansion.

APPLIED STATISTICS

I think you can perceive from this summation of the work of our Systems Analysis Department that we have generated the need for highly competent mathematical and statistical service. About three years ago we employed our first Ph.D. Experimental Statistician. In the last year we have added another man, a Mathematical Statistician, and currently we are endeavoring to employ a Mathematician with ability in numerical analysis.

I would give you the wrong impression if I left you with the idea that our Department of Applied Statistics serves only our Systems Analysis Department. We have recognized that our entire Industrial Engineering staff needs training in modern statistical concepts and techniques and in the newer developments in finite mathematics. That is even too narrow a statement. Our entire management group needs training in the design of sampling plans, experiments, and in the basic concepts of statistical inference. Our Applied Statistics Department is engaged in carrying out a broad training program designed to teach all levels of management what they need to know in this field. We have initiated parallel efforts within the Research and Development Department and the Engineering Division.

The last group is the Mechanical Methods and Construction Methods Department. Mechanical Methods, as we use the term, includes the whole process of methods study, planning, estimating, scheduling, and follow-up on maintenance work. This work is carried out in the plants by people trained in Industrial Engineering who report to the Plant Engineer. General program coordination and development, however, is an Industrial Engineering Division responsibility. These same procedures are also used in our field construction activities with certain of our construction contractors. Out of this program we have recognized that our best opportunities to reduce construction costs are through innovations in methods and materials, and we have undertaken projects on various high-cost components of construction, such as piping and insulation. These projects have as their objectives exploration of total-cost-in-place of new materials, or the effect on labor cost of major changes in tools and techniques.

STAFFING

For more than forty years our Company has had a policy of recruiting managerial personnel from colleges and universities. In recent years half of our manufacturing management have been college trained. The other half are promoted weekly and hourly personnel. Due to the technical requirements of the job, our Central Industrial Engineering Division is staffed almost entirely with college graduates. The present members of the Division have a wide variety of academic backgrounds. For example, there are: 9 Industrial Engineers, 8 Mechanical Engineers, 6 Chemical Engineers, 2 Electrical Engineers, 2 Other Engineers and Scientists, 9 men with Business and Economics degrees, and 4 Mathematicians and Statisticians. Eight of these people have advanced degrees of which two are Ph.D.'s.

Our turnover is low but our growth needs in the Division and our recruiting aid in establishing new Industrial Engineering organizations in the Company keep our recruiting quotas at levels approximating ten per cent of our enrollment.

As Director of Industrial Engineering, I have responsibility for meeting my recruiting quota with people who have real development potential for the Company. To select these people from available applicants, we have a number of aids. Our Plant Managers and the responsible personnel in other technical divisions are also engaged in recruiting. When they meet individuals interested in our Central Industrial Engineering activities, such applicants are referred to us. In this sense, we are represented, as a Division, on most of the major college campuses in the country. As a Company, we have devised an achievement test which provides useful information on how well a person has used his college opportunities. Final selection is usually made only after a day visit by the prospective employee to our operations in Cincinnati. Although a detailed discussion of our approach to training is not in order, we do believe strongly in on-the-job training and it is our intention to give a new man a specific responsibility within his first six months of experience.

The opportunity to work in the Central Industrial Engineering Division exposes a man to some of the problems of general manufacturing management and tends to give him a broad view of Company operations. It is also important in the early years of his Company experience to have close association with production operations. This is best achieved by assignment to a plant operation. It is our intention that the men who start in the Central Division, be transferred to the plants within their first two years. A number of promotional alternatives are available to them. If they are qualified and interested, they may become Department Managers, and progress in the line organization. If their interests lie in Industrial Engineering, a variety of experiences are available, leading to Plant Industrial Engineer. Or, after suitable plant experience, they may return to the Central Industrial Engineering Division in technical or administrative capacities.

My own experience illustrates this pattern of development. I started with the Company in Plant Industrial Engineering. After about 2½ years, I transferred to the line organization where I worked as Department Man-

ager, Group Manager, and Plant Manager. I assumed my present position a little over three years ago. My predecessor in Industrial Engineering now has a line responsibility.

THE FUTURE

In presenting our organizational structure, I made an attempt to indicate how it has evolved. It would be fair to ask, "What are probable future developments?" Here are three that we're thinking about:

1. One new organizational change is already approved. The Office Methods Department has been under line organization administration. After July 1st it will be a new department in the Industrial Engineering Division. With this change, our design responsibility for clerical procedures in manufacturing is broadened.
2. A second change would better fit us to keep up with developments in an important aspect of our field. You will recall that I stated our first objective is that the design of the job and the industrial environment recognize the needs and capacities of men. Since men, their needs and capacities, are involved in most of our design efforts, this has not been an appropriate area for specialization; all of us are involved all the time. There is, however, a growing body of research findings on man's capacities. There is even some information on man's needs, and much expressed concern about human values in industrial society. If we are to profit by the efforts of others in research and critical analysis in this field, we may need a person specialized in it, to interpret it to the rest of us. We are presently considering such a recommendation to our management.
3. One other development, from which future changes can be expected, is an increased awareness, by all functions of the business, of the value of specializing staff effort on cost reduction. With this we have seen the beginnings of increased staff cooperation across divisional and functional lines to propose changes in the corporate interest. Organizational approaches may be developed to promote and control these activities.

Factory Organization and Application

by **P. S. WILLARD**

Associate Director, Industrial Engineering Division, The Procter & Gamble Company, Cincinnati

AS MY part of the program I would like to explore with you these general concepts: What are the functions which we normally assign to the Industrial Engineering Department in one of our factories? How do these functions fit into the factory as a whole, and how do we implement and make use of these functions? As I attempt to expand these thoughts I hope to also discuss how we staff the factory organization and how we train and develop personnel in this field.

INTRODUCTION

Figure 1 is a simplified, and perhaps over-simplified, chart which relates the many functions carried out in one of our plants to each other and shows how responsibility is fixed in the various general categories. You will, no doubt, be led to wonder just why responsibilities are allotted as they are in some instances, and perhaps some of these will bear further discussion.

For example, you might wonder why mechanical methods are assigned to the Plant Engineer, rather than to the Plant Industrial Engineer, where it might more logically fall and where it, in fact, does fall in our central organization. Our reasons are these.

We have had a work measurement and incentive system for our production workers for many years. We have not yet been able to work out a satisfactory system for mechanical personnel. On the other hand, we could see a real need for study and examination of the methods and procedures used to maintain our establishment. To avoid even the slightest encouragement that our work in this field might lead to a mechanical incentive system, we decided to separate the function from the Industrial Engineering group. In addition, we felt that we might get better acceptance from the old line mechanical foremen and mechanics alike if the study came from within their own family so to speak. In practice it has turned out that this last reason is probably the more valid. Our mechanics still want the same bonus opportunity that production workers have and cannot see why we have not been able to provide it. Perhaps we will some day, but we are not there yet.

Quality control, job evaluation, and rate setting have never been a part of Industrial Engineering in our company because of the great store we place in product quality and industrial relations. It has been our feeling that these lines of endeavor justify specific staffing to give proper coverage.

On the other hand, in a few of our small installations we do have the management of the office under the direction of the Industrial Engineer, and I include it in this group throughout my discussion because I believe it will draw closer to this area as the "systems" concept, and the more extensive use of computers as management decision tools, develop at the plant level.

FUNCTIONS AND RESPONSIBILITIES

So much for the exceptions. Now let's look at the functions and responsibilities assigned to a plant Industrial Engineering organization. For many years work measurement and cost control *was* Industrial Engineering. Later in our company we also concentrated on methods with special emphasis on work simplification and work elimination. Cost analysis and economic justification has long been intimately associated with the Industrial Engineer's work. The preparation and control of the budget fell naturally into the hands of the Industrial Engineers because of their ability to predict from their cost control and work measurement data. Also, we believe it would be natural to include the statistician and system engineer of the future in the Indus-

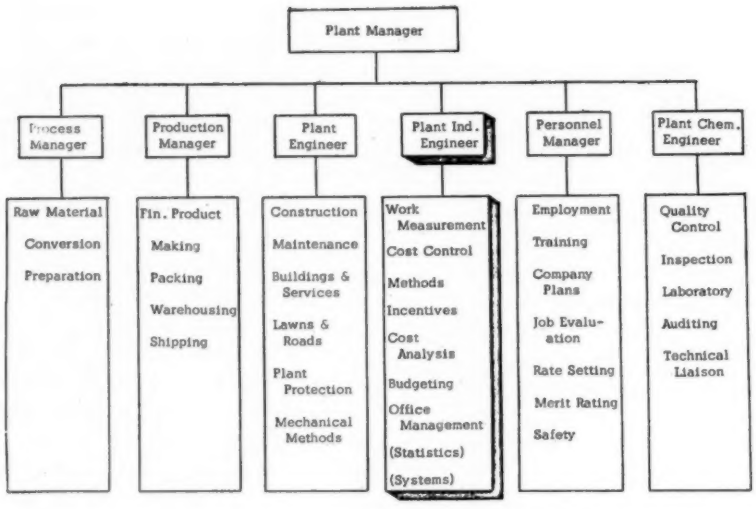


FIG. 1. Functional Diagram of a Plant Organization

trial Engineering Department.

Above all, the Industrial Engineering Department is charged with the responsibility to provide the local management with the tools and methods to do the best job possible.

It is all well and good to establish who has the responsibility to handle certain elements of a job, but it is more important to provide the methods and manpower to carry out these responsibilities.

Perhaps it would be easier to understand how we do it by referring to Figure 2. The responsibilities assigned to the Plant Industrial Engineer are divided into four main sections, and one of these has a dotted line connection. To avoid misleading you, however, I must hurry to explain that this diagram is more for illustration than to show the variations between plants that can exist in real life. In my experience, the limitations are almost always established by the number and caliber of the people available to man the section. In any case, one covers the basic responsibilities in the best way he can with the manpower available.

WORK MEASUREMENT

Work measurement, as I have used the term, is intended to imply that time studies and ratio delay studies (random work sampling) might be used under proper conditions. Generally, all work measurement which is used as a basis for incentive payments is established as precisely as we know how by a means of stop watch time study. Work measures which are used to predetermine crew sizes or work assignment might be established by random work sampling. Most of the work measurements of the laboratory analysts or mechanical maintenance crews have been by work sampling. Elemental data are sometimes used to establish a job standard in advance, but these are usually superseded as soon as proper time studies can be made.

I have referred to an incentive system based on the time studies made of the various jobs. The bonus possible under our incentive system is responsible for the success of our entire work measurement program. Unlike many concerns, our people are usually requesting that we hurry up and get their job on standard, rather than the often reported attitude of resistance. I wouldn't want you to get the idea that we don't have our troubles occasionally, nor that we don't hear the age old lament that this or that standard is too tight. We do, and sometimes this feeling can be vigorously and vocally pursued.

BONUS

Our bonus is paid on two chief criteria. The most common method is a direct payment for doing more standard work than the clock hours worked. This applies on all jobs where the work can be measured accurately and where instantaneous judgment or decision is not a major contribution. In some fields of endeavor, however, the manual work is of less importance than some other factor, say quality or rate or speed. In this case, a chart has been prepared which allows extra payment for extra good output, even though the manual effort was not in excess of the clock hours worked.

We like to think of bonus earnings in the range of 20-30% as being about right; that is, supplying sufficient incentive without an unreasonable work load.

COST CONTROL

It was evident at an early stage in the development of Industrial Engineering techniques in our plants that much money was to be saved in the fields under the control of department management personnel. Selection

of these controllable costs, establishing an ideal cost, and measuring the actual costs from month to month became our cost control system. The performance against one of these ideals, or performance factor as we call it, made possible a measure of an individual contribution and an incentive system for management people.

Cost control has been extended to such areas as: wages, direct and indirect; the repair and maintenance of equipment and buildings; the loss and depreciation of raw material including reworking and repackaging costs, and the actual disappearance of material or goods; the cost of steam, water, fuel, power and other services. Almost everything is covered if the total annual cost is large enough to justify spending the time to establish the ideal. In most plants over 80% of the controllable costs are covered.

METHODS PROGRAM

Development of a methods program was a natural evolution following the success of the time bonus or wage incentive and cost control programs. From the beginning of the methods program there has been no area in the manufacturing operation that has escaped from the Methods Engineer or the Methods Team. Capacity bottlenecks, flow of paper work, watering the lawn, warehouse operations, mechanical tools, pump packing are among the many and varied problems which were tackled. The keynote was—Why? Why? Why?—isn't there a better way, cheaper, safer, easier. There always was one when we looked hard enough for it. But were we on the right track as we tried to simplify our jobs? What could we accomplish if we didn't do the job at all? Obviously, you would save all the money. So, a new text was developed, "But for what basic cause could this job be eliminated?" The modern concept of our methods teams is to eliminate the job and save all the cost; to simplify only when it is proven impossible to eliminate.

The approach toward mechanical methods improvements has been carefully planned to avoid suspected resistance. Many of our craft foremen were promoted mechanics and had been on the job for a long time. These men, together with many older mechanics, were not apt to look upon new-fangled ideas with any enthusiasm.

ESTIMATOR

So we developed a position of Job Estimate Engineer with responsibility for serving as a staff man to a mechanical group. He would translate the foreman's observations and experience into carefully preplanned jobs with a tool list, a material list, an estimated time, necessary sketches and detailed plans for any unusual possibility. He would arrange with the operating foreman to have the equipment available for repair at a given time to avoid delays. Finally, he would schedule not only each day's work, but the entire week ahead for every mechanic in the crew. Only major breakdowns could interfere with this schedule.

By using random work sampling techniques, we have estimated an improvement of from 40% to over 60% in the actual effective work done by maintenance people as a result of this program. To avoid any adverse psychological impact on the people involved, we have reduced crews only by normal attrition and taken up the slack by the extra work done by each man. Similar savings in material, storeroom inventory, and emergency downtime for vital equipment have also resulted. These accomplishments took place in an activity that we thought was a relatively efficient operation. We know now that there is still a very fertile uncultivated field from which additional savings can be realized.

FORMS AND REPORTS

Following my analogy to the uncultivated field a bit further, I'm sure you will all agree that nothing grows quite like weeds, bad habits, and paper work. We have invented chemicals to control the weeds, developed will power to defeat the bad habits, but nothing seems to slow down or stop the flow of paper. We have made some

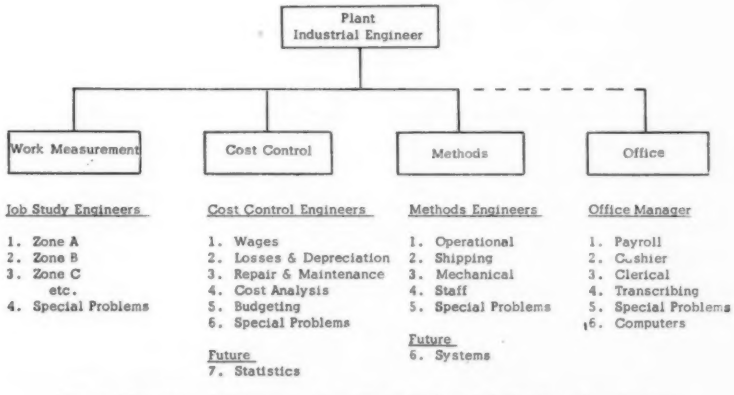


FIG. 2. Functional Diagram of a Plant Industrial Engineering Section

efforts, however.

Staff studies are a regular activity. Our staff engineer observes the preparation of the forms and reports: questions the need for reports, the number of copies, the method of duplication; evaluates the effort expended; and generally determines whether to discontinue the report or not. In some cases reports are discontinued for awhile to see if anyone misses them. No squawk, no report. At least this proves that no one is using the report and provides a clue as to its need.

TEAM—GOAL APPROACH

In our plants, the most effective tool to maintain interest in a good Methods effort is the team-goal approach. Line supervision, mechanical people, and other staff specialists serve on a team with the Methods man acting as secretary. Team goals are established based on definite projects; the projects are discussed and assigned to a team member. Regular meetings are held to report and discuss progress. Success stimulates other successes and competition with other teams keeps interest and effort high. We measure success of this effort by using the dollars saved per member of management in the plant. Our 1958 goal is $7,000 per member of plant management. This is based on improved methods and does not include policy decision changes and the like.

ANALYSIS OF COST OF OPERATION

An important function in any organization is the analysis of the cost of operation. Whether probing for hot spots or distributing the costs to the proper department or to the proper product brand, this work cannot be neglected. The accounting in our plant organization is handled by the Comptrollers Division, but the Industrial Engineering Department is vitally concerned with the cost figures since they are used in cost control, cost distribution, cost justification, economic studies, and in establishing and controlling the budget. We expect all members of management to be able to make their own cost justifications, and to be responsible for their share of the budget, but we look to the Industrial Engineer to coordinate these efforts and serve as an advisor on all cost matters.

OFFICE MANAGEMENT FUNCTION

As I mentioned earlier, it is not typical to include the office management function in our Industrial Engineering section of the plant. In the smaller, more integrated plants, however, the association is a logical one. It may well be true of larger units as well. The logical developments of the information flow theory and use of computers for other than routine commercial activities fall in an area of activity which is closely allied with our concept of Industrial Engineering work of the future. It is for this reason that this function is included in my discussion today.

THE FUTURE

What are these future developments? We see an extension of the use of statistics and the theory of probability to all our management activities. What can be done to simplify management decision or give management the decision ready made? What items can we remove from the judgment area and make routine? We believe that these questions can best be answered by extending the idea of Systems Analysis to the plant organization. Linear and dynamic programming, mathematical modelling of all types require computer solutions in many cases. Where and how far can we expand into these new fields justifiably? We don't know as yet, but we do see work along these lines in the crystal ball.

ORGANIZATION

So much for the functions of Industrial Engineering within the plants. Now, how do we organize to handle these functions; what are the types of people we use; what are their opportunities? In our typical plant, the personnel in the Industrial Engineering group will consist of people of many different backgrounds, and we feel that this is important in carrying out the functions I have described to you. For example, our Job Study Engineers may be graduate Industrial Engineers recruited on the college campus, they may be college graduates with economics or business administration backgrounds, they may be promoted from the ranks, and it is not unusual for some of the Job Study Engineers to be line men assigned to this activity as part of their development.

Obviously, such people might have a multitude of different backgrounds. But we feel this is basic. Men from the line should be given experience setting job standards, making work measurements, so that they can better go back to their jobs and administer the plan in an efficient fashion.

By the same reasoning, we feel that Industrial Engineers, or people whose careers seem to be directed toward staff activities, can do a better job if they have been given an opportunity to work for awhile on the line and can better appreciate the problems and difficulties that a line manager encounters from day to day. These Job Study Engineers, based on their own abilities and capacities, are commonly assigned a variety of activities, with their first responsibility to the establishment of proper job methods and proper work measurements in a given zone or area. They are also called upon to help the line managers explain the standards, and extend the use of standards to new areas not previously covered.

This, in itself, is an interesting assignment for a young man, but to further develop the individual, broaden his viewpoint, and to make him first a better Job Study Engineer and possibly a better management man for the company, we pile on special assignments of a great variety.

COST CONTROL ENGINEERS

Our Cost Control functions are broken down in many general fields depending on the size of our plant and the quantity of work to be covered in each of these fields. Each Cost Control Engineer is assigned one or more of the functions to the extent of his ability to handle the job. Cost Control Engineers come from a variety of backgrounds too, some of which require special equipment or knowledge to do a satisfactory job. For example, if some one is going to calculate the ideal amount of steam to heat a tank of oil or run a pump or turbine, or if he is going to calculate the electrical power necessary to maintain the operations of a particular department, he must have some engineering knowledge. Backgrounds such as mechanical engineering, industrial engineering, electrical engineering, and the like are all used in this area. On the other hand, the man who is attempting to establish and account for all the raw material that comes into the plant and goes out as finished product would have a better understanding if he were trained along the lines of a chemical engineer, or at least was exposed to college Chemistry.

Our Cost Control Engineers are charged with the responsibility for developing ideal allowances. They are also charged with the job of determining the actual performance against these ideals, studying the resultant performances, encouraging improvements, helping the line organization get their house in order. This can be a big job, and as you can see, cross training between the line organization and these Cost Control jobs is very helpful and occurs frequently in our organization.

Another source of personnel is from among the hourly and weekly personnel. Over the years we have been quite successful in building up an alert, vigorous, plant Industrial Engineering organization by blending in some of the better men from the ranks. Our over-all management group, including the line supervision, is made up of approximately 50% each of people with college training and people who are promoted from the ranks.

TRAINING

Regardless of source, our policy for training is to develop a custom-built training program for each individual based on his own background and the requirements for the job. The time allotted for training is varied to suit the individual's progress in acquiring the necessary information. As an example, however, we usually consider at least three months of "do it" style training necessary for a Job Study Engineer with a college background in Industrial Engineering. A longer time would be necessary if the technical training is not accomplished in college. The Cost Control Engineer on one of our more technical jobs would receive formal training for only a few months if he had had previous company experience, but would not be fully effective for quite some time because so many of the things that he has to do would not occur every month. An example of this is the preparation of the semi-annual budget, to which our Cost Control Engineers contribute greatly.

It is possible to train any intelligent person to understand the best procedures for developing a good Methods program. Like all other activities, however, we have found that our more successful Methods Engineers are those men with an alert, inquiring, open mind, driven with boundless energy and enthusiasm. This type of person is best able to inspire other members of the Methods Teams to greater activity, and as a result, achieve the greatest goal.

Obviously, a person of this caliber doing a good job on a Methods program will soon be in demand for bigger jobs, either in the staff or line organizations. Progress will be influenced, of course, by the personal characteristics of the individual and the decision on the part of management as to how he would best fit into the organization. The individual's own desires are given due consideration. All this ties in closely with our philosophy that we hire people for careers with the company rather than to fill a specific job, and that one of our big responsibilities is to develop people for top management positions in the future.

CONCLUSION

The person who is our Industrial Engineer has had much of the training described and has filled more than one of the assignments. However, this has not always been true. I can remember quite well an incident that took place 25 years ago when our Industrial Engineering activities were still quite young. There was naturally much resistance toward this new-fangled procedure. In a meeting one year, one of our chemically minded people was very much concerned about how this time bonus incentive activity encouraged operators to cut corners and perhaps make a poor quality product. This man made a rather impassioned talk on the subject and seemed completely opposed to any idea of expanding this incentive system to many of the more important quality jobs. The next day it was announced that this man had been appointed as a Plant Industrial Engineer in one of our plants, with a comment that anyone who feels so strongly is a proper person to install our Industrial Engineering techniques with the proper safeguards for quality. I might say that it worked out very well. Nor is this situation completely untypical. Both Mr. Forberg and I entered our present positions from the positions of Plant Managers.

I have one other question I had hoped to be able to answer for you and that is, "What does an Industrial Engineering Department mean to a Plant Manager?" If you will consider for the moment that the foregoing remarks have been the opinions of an ex-Plant Manager, and the description given was in reality a description of how a Plant Manager had used his organization, perhaps in a

way I have already answered the question. It has been my opinion that the successful operation of any unit of a business is dependent upon a systematized approach. Certainly then the use of an Industrial Engineering Department is a tremendous move in that direction. As a matter of fact, perhaps it would be well to say that Industrial Engineering is a systematized approach to management. Industrial Engineering supplies the tools for control, the measures of success, and the more efficient objective for tomorrow.

Administration of Industrial Engineering

by **GEORGE H. GUSTAT**

Director, Industrial Engineering Division, Eastman Kodak Company, Rochester

INDUSTRIAL Engineers have accomplished a great deal in the past 20 years in assisting their managements to make a profit. Profits, incidentally, are the index by which you measure the success of an enterprise. You know it's the socialist's idea that making profits is a vice. I consider that the real vice is making losses. Generally, a good Industrial Engineering job and profits go together. A man who can save money isn't a miser—he's a wizard!

Progress then is dependent on the success of our aggregate business successes. One might well reason that good "Industrial Engineering is Progress."

Good Industrial Engineering Departments do not just happen. By the very nature of the endeavor they are not calculated to win very many popularity contests.

For one to be good requires the usual ingredients that make any kind of an organization good. There are probably a great many of these factors, but I will only list a few:

1. Strong support by top management.
2. Capable leadership (or good administration).
3. Selection of effective personnel.
4. Training and follow-up.

I was asked to talk on "Administration of Industrial Engineering," but specifically about our own set-up at the Eastman Kodak Company. I can promise you to be candid about this, but perhaps not impartial.

Since even Industrial Engineers need administration, this talk will cover three points:

1. Status and functions of Industrial Engineering at Kodak Park.
2. Selection and control of projects.
3. Development and appraisal of engineers.

STATUS

Let me visualize for you as a first step the type of plant we will be discussing. Kodak Park is the largest of the Eastman Kodak Company plants in Rochester. It is large enough to be practically a self-contained unit of manufacturing enterprise. The plant covers 1,000 acres, contains about 115 buildings and has its own railroad and bus lines. We employ about 20,000 people and maintain our own medical, fire, water and power plants. We manufacture about 35,000 different items that include photographic film and paper for the amateur, professional, and commercial industries along with many lines of chemicals and sundry items for the consumer.

Our Kodak Park organization (Figure 1) is established by manufacturing divisions that produce our sensitized films, paper and chemicals. We have also several service divisions that include Purchasing, Medical, Industrial Relations and others. The Industrial Engineering Division is classed as one of the service divisions. The function of each of these is to act in a staff capacity in servicing the various production divisions and the plant management. In the job of assisting the plant in reducing their costs of operation, our role is that of a staff service without line authority.

FUNCTIONS

The general functions of Industrial Engineering may be outlined as Methods, Measurement, and Incentives. We have organized our division by two major departments that are known as "Engineering Methods" and "Work Measurement." Within each of these departments, we are organized so as to closely follow the lines of the general plant organization. That is, in each Industrial Engineering Department we have an engineering group established to service the film division, another to service the paper division, and so on.

In our Engineering Methods Department, we employ about 115 people and the specific functions of this Department are: manufacturing methods, layout planning, package engineering, equipment studies, product design, process engineering, statistical quality control, etc. Among the more common techniques used in this area in project analyses are the flow, process and man-machine charts, standard data, MTM, etc. We maintain our own package testing laboratory and model shop. Here we perform many types of simulated package testing using various pieces of equipment designed to enable us to evaluate shock, compression, and vibration. In the model shop we develop prototype fixtures so that a process or area can be visualized and demonstrated from working models. Several of our more complex layout and expansion studies have been prototyped using 3-dimensional scale models.

In our Work Measurement Department, we employ about 235 people. Specific functions are: work measurement, wage incentive plans, auditing, research and development and training. Familiar techniques here are the stop watch for time studies, MTM, and statistical analyses. Our own peculiar techniques include a diversity of uses in time lapse photography, micro-motion analysis,

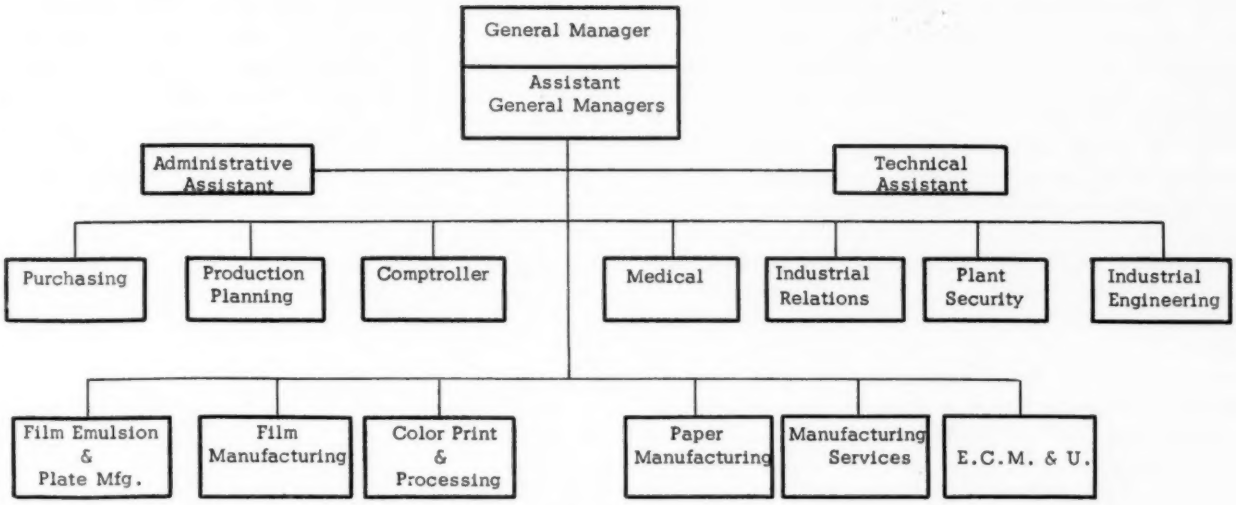


FIG. 1. General Management Organization Chart

operation sampling, and ratio delay studies. Because of our many darkroom operations, we use a portable sound scriber that records operations as verbally noted by the engineer on a tape that can be transcribed and equated with the elapsed times of the operation study.

The principal customers of Industrial Engineering are the production divisions noted on the plant organization chart. However, we do a great deal of engineering work for the plant management and for other staff and service divisions. In addition, we have several Kodak customers outside our plant such as the Recordak Corporation, Canadian Kodak, and our various sales branches which are located in various parts of the country.

SELECTION OF PROJECTS

There are several factors that are fundamentally the reason for our customers requesting our services. These are related to: capacity, technical improvement, safety, cost reduction, employee relations, new products, competition, and sales. One of the most important, naturally, is caused by our sales growth. The Company's sales were $275 million in 1946 and $798 million in 1957. During the long inflationary period dating from 1939, our selling prices have only been increased by 32% while labor and material prices have increased substantially. This has required new departments, increased capacity and general expansion. Ever continuing programs of cost reduction, personnel safety and employee relations have also contributed a great deal in our engineering workload. Technological improvements and the introduction of many new products have likewise furnished us with a multitude of complex assignments.

An idea or need for an assignment logically starts with our customers. However, a little more than half of our total assignments at the present time are the results of our engineers spotting needs in their areas or in their creation of new ideas. These are discussed with the production supervision and if an assignment request is approved, the project is initiated for study.

Our assignment form details who will do the work, the hours required which is in effect the cost estimate, and the scheduled completion date. It indicates the scope of the job and the purpose of the investigation. We have between 1000 and 1500 assignments in process at all times with 4 to 8 assignments for each engineer.

CONTROL OF PROJECTS

We have established two types of control for our engineering projects. These are defined as "Assignment Control" and "Budgetary Control." In our assignment control, we are concerned with communication and coordination, progress reporting and results. In budgetary control, we are concerned with our service and cost to the customers. We operate on a direct charge basis so that our customers are billed each period for the engineering hours spent on their assignments during the previous period. We are also very much concerned with our effectiveness as an engineering division. As a staff department offering a service, you may rest assured we are much concerned with our charging rate to our customers as they alone make the comparison of engineering costs versus value received.

The engineer on the job is one of the key men in our assignment control. He has the responsibility for two-way communication with production foremen and other staff units concerned with the project such as the Accounting Department or Purchasing Division. He plans the project study, contacts to be made, establishes the schedules for cost estimates, visits from vendors, installation plans and follow-up. Once each four-week period, he prepares a progress report for each assignment that has progressed during the period, schedules plans for the coming period,

and reports hours expended to date. These are reviewed with his supervisor who prepares an over-all assignment analysis of all activity in the area. This is referred to as an assignment summary and is reviewed with the production superintendent.

At assignment completion, the engineer prepares a brief closing statement that outlines the problem, analysis made, and the results of the study. A formal report, in somewhat more detail, is issued to the production superintendent. This report is prepared by and issued over the signature of the engineer who has made the study.

From the standpoint of budgetary control, we endeavor to place control responsibility at the source or with the group supervisor. All assignment activity in his area is billed out at a standard rate per hour. This rate includes the cost of engineering labor, plus a proportionate cost of the division's indirect labor and expenses of operation. The group supervisor is probably the key man in determining our budgets and manpower requirements for the division. During the latter part of each year, each supervisor meets with the production supervisor to establish a budget for the coming year in terms of assignment hours for Industrial Engineering service. This budget approves assignment hours for the completion of projects in process, assignments previously approved but not yet started, and an amount for future projects, both known and estimated.

Our administrative section summarizes all customer budgets into a departmental total of customer approved assignment hours. To these figures are added the proportionate amount in hours for indirect labor such as vacations, training, absence, etc., and the indirect hours budgeted for supervision, staff and clerical. In addition, we establish a sizeable budget in terms of engineering hours for research and development in the area of Industrial Engineering techniques and these hours are added also to our direct and indirect total. A summation of all hours (direct, indirect and research) represents the budgeted total of hours that we estimate as the requirement to run our department. A simple calculation then converts our budgeted hours into manpower. An evaluation through the use of appropriate rates converts our manpower requirements into the department's labor budget in terms of dollars.

Two other budgets are prepared, the first defined as our trip budget (cost of seminars, conferences, etc.) and the second a budget for operating expenses such as supplies, cleaning services, telephone costs, depreciation, etc. The addition of our budgets for labor, trips and expenses represents our total estimated cost of operations. Based on this total budget, we are in a position to evaluate our manpower needs and consider this factor in establishing our hiring policy. This policy itself considers many other factors such as rate of job offers, acceptance ratios, and engineering losses. It is made complex by fulfillment of a previously stated Industrial Engineering function—that of providing technical personnel to the plant. Our losses in this respect, at least to the Industrial Engineering Division, are sizeable and present a real problem in maintaining experience levels of engineers and our service commitments to the customer.

From our total budget figures, we calculate also the rate per hour that the plant will be charged for our services. This is obtained by dividing total budget costs, less a credit allowed by our Management for the excess costs incurred in constantly training new people, by the total assignment hours budgeted for and approved by our production customers. This results in a standard rate per assignment hour and is used throughout the year. This rate and our budget are reviewed with the Comptroller's Division, and approval by our Management sets it in operation.

The cost awareness on the part of our plant supervision reflects in the hours spent by our engineers on their assignments, the charges that are billed and the results obtained. As each of these departments may exercise an accept-or-reject attitude regarding our services, we attempt to operate as effectively as possible and give each customer the greatest value for his dollars expended. With this in mind, we closely follow the costs of operation in each area. This is again controlled at the source and the primary person responsible is the first line group supervisor. To hold him directly responsible, we feel that he should be provided with all necessary data required to operate his unit effectively. In doing this we have established a system whereby the engineer accounts for his total hours on an activity sheet. This is done daily and each engineer records his hours spent on each assignment or indirect classification. At the end of the period (4 weeks), these are totalled in our clerical section and turned over to the Tabulating Department for key punching on IBM cards. The next day, two reports are issued, one to Industrial Engineering in terms of engineering hours, and one to the Accounting Department in terms of engineering cost. The Accounting Department bills each production customer according to the burden account shown (part of Industrial Engineering assignment number) and the dollars charged (assignment hours at standard rate).

The report issued by the Tabulating Department to Industrial Engineering, in terms of hours, is sub-divided as follows:

1. By each group supervisor—supervisor control number is key punched from engineer's activity sheet.
2. For each supervisor's area, all assignments are detailed by:
   a. Title and job number—furnished to Tabulating when assignment is approved and initiated.
   b. Engineer—from recordings by job number on activity sheet.
   c. Hours charged—from engineer's activity sheet.
   d. Budget hours—furnished annually based on production department approved budget for engineering service.

Along with his assignment analysis, each group supervisor receives a listing by classification of all indirect charges such as training, clerical, etc. From this information each supervisor has the transactions of:

1. Hours to be billed for the past period.
2. Hours billed year-to-date.
3. Budgeted hours for the period.
4. Budgeted hours year-to-date.
5. Relation of his indirect activities to assignment activities.

On a quarterly basis, our administrative section prepares a report that examines our departmental efforts in terms of customer budgets and actual charges, and what the Company has realized from our work. This report brings together, by each geographic area, the summary figures from the tabulated runs and the results as shown on our assignment closing statements, subdivided by the various engineering functions such as cost reduction, expansion, new product, etc. Along with the pertinent figures, each group supervisor prepares a condensation of his group's activity in terms of personnel, special assignment information and the future engineering plans. These quarterly reports are one of the principal means by which the Directors of the Division are kept aware of the division's financial status and operating effectiveness.

On a period basis we prepare an analysis in terms of percent of indirect hours to assignment hours for each area. This report is used as a continual check on the overhead cost of indirect labor. At the same time a workload analysis report is prepared to determine the current and future workload status of each area. These figures are a part of the previously mentioned tabulated reports and represent a minimum of clerical effort in compilation.

Once each period we examine our division budget and actual expenditures in the form of a personnel analysis, personnel losses, labor and expense variances, and, if required, prepare a schedule of revised plans.

These are the formal operating and budget controls administered by our group supervisors and administrative section. From these relatively short period or quarterly reports, we are kept abreast of what has happened, the cost and results of such happenings and the supervisor's plans for the engineering activity in each area for the coming quarter.

This system is not designed or intended as a substitute for sound judgment on the part of our supervision or directors. When occasions arise, and they do, that require action, expediency and sound decisions, we expect and do handle these on whatever personal basis is required by the occasion. What we have attempted to do is to free our supervision from bogging down with paper work and non-engineering essentials.

DEVELOPMENT AND APPRAISAL OF OUR PEOPLE

As we discussed, we hire many engineers that are eventually recruited by the plant for their operations. For this reason we have established an extensive training program to broaden the background of our personnel in fitting them for their Company careers. Although we operate an Industrial Engineering Division, our plant is basically a "chemical" organization. Many of our former engineers have been transferred to positions leading to staff and supervisory jobs in the production areas, some even becoming members of a production department's top management. With all these factors in mind, we have attempted to staff our organization with a diversity of engineering backgrounds. This program leads us to hire predominately industrial, chemical, and mechanical engineers, but with a significant representation in the engineering fields of mathematics and electronics.

We schedule these people for our own division training program to make certain that all engineers are equipped to handle the normal flow of Industrial Engineering assignments. Their general orientation course is handled by the assistant directors and director. This course outlines the Company and plant organization structure, our competitive position, our division organization and functions, and other items in this category.

These courses are spaced throughout the engineer's first two years of employment as they are somewhat complex and we believe, thorough. We feel also that the new engineer should have his own assignments and responsibilities as soon as possible, so his training is interspersed over quite a period of time. We strive to keep our technical information on an advanced basis so as to keep our training courses effective.

Our people also participate in several Company sponsored training programs. These training programs cost the Company a good deal of time and money, but our Management feels the investment is wisely made. We transfer about 20 engineers to the plant each year, and these men must have at least two years' experience in our division. The benefits to the plant in using our division as the basis for their recruiting are numerous. They are in a position to consider several candidates; all candidates have been well indoctrinated in Company policies; each man has a working knowledge of the plant's operations; we have a reasonably good indication that the engineer is making Kodak his career; at least two years of performance reviews are available, and the customer has the benefit of our recommendations.

Our Management provides us with a special budget allowance that amounts to 25% of our total budget in carrying out what we define as vestibule training. As a side comment, this program for the plant is not without benefit to our division. Many of the key positions in the plant today are filled by former members of our division. Also, the whole history of our vestibule training functions has been to continually promote a greater understanding of Industrial Engineering throughout the plant.

In order to provide outstanding people for these plant positions, to have well trained and effective engineers on

the job, and to develop in our people a sense of prestige, recognition, and responsibility, we have an appraisal program intended to evaluate our progress in these objectives.

In this respect, we have personnel interviews with each engineer at intervals of three months, six months, one year and two years. These are not a progress or performance review, but are centered around the man's aptitudes, job satisfaction, the area of his assignments and the challenge of his work. They are handled by the top supervision of the department, including the assistant directors and the director. They provide a means of free expression on the part of the engineer and let him realize the interest we have in his career with Kodak.

We have a rate review procedure on a semi-annual basis. The basic thought here is a monetary recognition of past performance. Recommendations are made by the engineer's supervisor and correlated across the division for consistency in performance evaluation. We freely discuss job classifications, and salary ranges within each, that are available to the engineer and the performance expected for every job.

Our progress review is also on a semi-annual basis, but the basic thought here is an evaluation of progress in order to point out strong characteristics and those requiring improvement. We use the Company progress review form supplemented by characteristics pertinent to our business as Industrial Engineers. Our people, along with being good engineers, must sell our services, must constantly create new means of operation improvement and must be able to work with people of varied backgrounds under many different sets of circumstances. For these reasons, we are extremely interested in an engineer's creativeness, his initiative, his emotional stability in dealing with people, his technical and analytical excellence, and the manner in which he expresses the results of his efforts.

Our progress review procedure is initiated by the group supervisor's rating, correlated with other levels of supervision at a correlation meeting. This meeting provides us with information on the progress of all engineers and insures us that we have a constant application of performance techniques. For each job class, we have a detailed description that describes "good" performance characteristics. Likewise, we detail what is expected for both the "very good" performance and the requirements for a man to be "outstanding."

Probably the most important aspect of our progress review is that in his evaluation, the supervisor making the rating must set forth the engineer's strongest characteristics, those requiring improvement, and most significant, his recommendations and program to assist the individual in improving his performance and making further progress. In this program, we often find recommendations for further training courses and in some cases, special courses outside the Company. The entire progress review, with the supervisor's recommendations, are reviewed with the engineer against the engineer's job classification. A discussion takes place as to what is needed to improve performance, not only to a higher rating within that job class but also to progress to the next job class. The notes, recommendations, and the engineer's comments are all made a part of the progress review sheet. These are filed in a central section for future reference. All guidance, coaching and follow-up are a direct responsibility of the group supervisor, with all other members of supervision available for assistance.

In these ways, by means of personnnel, rate and progress reviews, we attempt to offer as much as we can both from a Company and Divisional standpoint to each engineer in his own program of development. He clearly understands what is required to attain each goal and degree of performance. He understands the value of free expression, the challenge of competition and the knowledge of where he stands in the organization, and the requirements of the job ahead. Our Company has a reputation for a sound philosophy in the treatment of its employees. I'm sure this has an effect on our rate of turnover. The rate of engineers leaving the Company is only a fraction of the national average. We like to think that a portion of this is due also to the approval atmosphere that has been created in our Engineering Division.

SUMMARY

What I have talked about is a very brief description of our plant, the functions of our Industrial Engineering Division, how we get Industrial Engineering jobs to work on, how we control these jobs. After all, Industrial Engineers are really overhead. Overhead costs need control just as any other costs do, so the "doctors" should take their own medicine. Finally, I have covered what we do to really know what sort of a job our men are doing, and the steps we take to make sure that they continue to develop.

Management of the Industrial Engineering Function

by **WARREN E. ALBERTS**

Vice President, Industrial Engineering, United Air Lines, Inc., Chicago

INDUSTRIAL Engineering is one of the newest and most rapidly developing professions in the country. It is not too surprising then that its function will vary from company to company and its basic services performed under many different names and titles. So, before getting too deeply into the subject of managing the function, you should know what we consider the Industrial Engineering function to be in United Air Lines and how we've set it up to serve the company. After that, we'll talk about some of the problems facing the Chief Industrial

Engineer in allocating, assigning, and developing his department's efforts.

THE INDUSTRIAL ENGINEERING FUNCTION

The Industrial Engineering Department in United reports to a Senior Vice President—Economic Controls who has no operating or line responsibilities, but who is responsible for planning and controlling the economic growth of the company. His other department, "Business Research," includes such functions as Airplane Schedules, which in effect sets the over-all production plan for the company; Cost Control, which operates the budget system and profit plan program; and Economic and Market Research, which makes economic forecasts, studies our markets and public reaction to our services. There is no question in our minds but that our organizational placement has given us an objectivity and freedom to pursue problems wherever they may lead which is not present when the Industrial Engineering function reports to a man who has operating responsibilities in one specific area. Another advantage is that our President foresaw the value of this internal consultant-type activity way back in 1940. This enabled the department to develop those functions which we felt were part of this young profession and not have them pop up all over the company as staff specialties.

The department's headquarters are located in the Executive Offices in Chicago and include certain specialized functions which are not duplicated in the two field groups which service our key operating administrations. Figure 1 shows the organization of our Industrial Engineering. The department consists of four divisions—Organization Planning, Regulations and Forms, Operations Research and Applied Science, and Work Analysis, each with company-wide responsibility for their area of activity.

The Organization Planning Division is responsible for planning and guiding the company's organizational growth. It includes responsibility for establishing levels, relationships, job worth, titles and basic responsibilities. Much of its routine work is performed by people in the operating departments leaving it free to concentrate on developmental work and special organization studies. To us, Organization Planning is an essential part of Industrial Engineering because it makes little sense to spend large quantities of effort on an operation which is not organized to use the human resources available to it in the best possible manner.

Frankly, I can't see how an Industrial Engineer can separate an identification of the job to be done with the organization of the people to do it. This responsibility has also enabled us to encourage the formation of qualified groups within the various operating departments to carry forward our work in specialized areas. Although these people do not report administratively to us, they look to us for functional guidance and do a job which I don't think could get done as effectively in any other way.

The second division, *Regulations and Forms,* provides the company with a uniform method of communicating with the people in the field through a system of regulations and manuals. Although the operating groups prepare their own material, it is put into a format for best use by our Regulations Editors. As you can immediately appreciate, this also gives our other divisions early warning of the changes in procedure and policy the operating people are considering. The other principal responsibility of this group is the control of reports and forms, plus

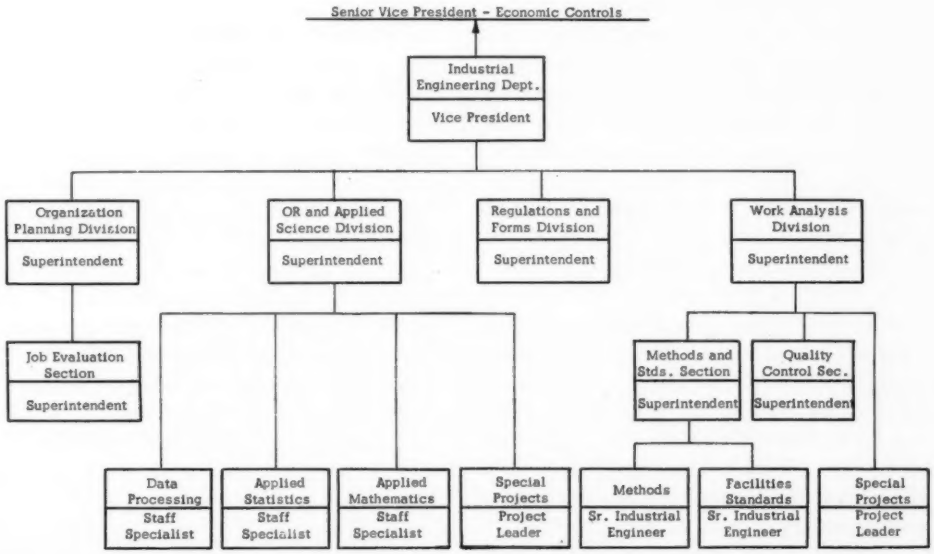


FIG. 1. The Central Industrial Engineering Organization, United Air Lines, Chicago

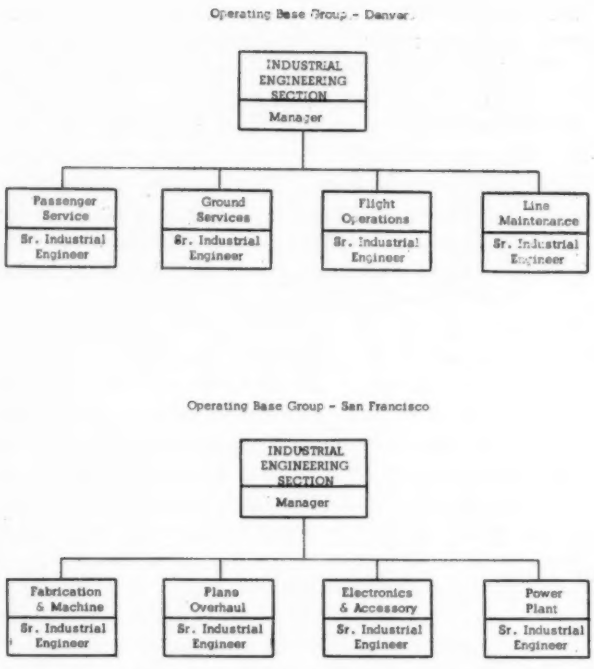


FIG. 2. Industrial Engineering Field Organization, United Air Lines

special analyses in the paper work and filing field. This group has field service groups in both Denver and San Francisco.

The Operations Research and Applied Science Division was established to dig deeper into some of our operating problems, plus providing a service to our engineers and the company in developing and applying some of the techniques from other sciences. As of right now, we have specialists in the fields of integrated data processing, applied statistics, applied mathematics and system analysis. This group tackles major projects on its own and is also used by other engineers for consultation on technical problems. This group also has the responsibility of developing and evaluating computer applications within the company. Although we scoured the country to man this group, all of the men came from within the company, and have already made major contributions in the field. In fact, it has brought home a point which many Operations Researchers and Scientists are just beginning to realize: That is, that knowledge of a particular technique or theory is the smallest part of the job. Unless there exists a man who can see applications and bridge the communications gap, productivity will be nil.

The Work Analysis Division is the oldest and also the first one formed in 1940. It has system-wide responsibility for work measurement, methods, and standards. Over 75% of the 20,000 people in the company are under some form of work measurement, with 10,000 being under a formal standards program. Believing that one cannot separate the measurement of quantity of work from quality, our company's quality control program is also sparked from this division. We have done a lot of work in the measurement of service levels but have only scratched the surface in the over-all control of quality. This division also has the responsibility for establishing facility standards and resolving problems in this area between departments. The fourth activity is one which we simply call "Special Projects" and it is likely to be assigned, and is capable of handling, almost any type of problem.

Now, let's jump to the two field groups (Figure 2). They actually report administratively to managers who handle all of Economic Controls' activities at Denver and San Francisco. They, however, are functionally responsible to the headquarters' department. These field groups are organized on the basis of a Senior Industrial Engineer representing all of our services to a key department or area within the company. You will note in Denver that one Senior Industrial Engineer and his group serve the Passenger Service Department while others take care of Ground Services, Flight Operations and Line Maintenance. Over 6,000 field people in some 80 stations over the system are represented by these operating groups who have their headquarters in Denver. These Senior Industrial Engineers are each charged with the responsibility for the work measurement program in their area, plus providing an all-around consulting service. We do not expect these men to be top-notch specialists, mathematicians, etc., but to be well rounded men who can diagnose problems and know when to call for specialized help.

The group servicing the Overhaul Base is somewhat more fortunate insofar as travel goes in that the entire operation, involving some 3,000 people, is performed at one location. Therefore, this group has been organized with a Senior Industrial Engineer assigned to each one of the key shop areas.

ALLOCATION OF EFFORT

One of the continuing problems facing any Chief Industrial Engineer is in the proper balancing or allocation of his effort. This is simply recognition of the fact that as the company's needs or its environment change, the return on various types of Industrial Engineering effort will vary. There is no point in allocating all of your effort to the installation of a work measurement program when what is really called for at the time is a complete overhaul of the production system. This is like a doctor concentrating on setting a finger when all along he knows the hand should be amputated.

As you have probably guessed, we are set up for a continuing effort on three different levels with the ability to vary that effort depending on expected return per Industrial Engineering man-hour invested. These levels are as follows:

1. *Effort directed to getting the most out of the present system.* This, in most companies, includes work measurement, job evaluation, quality control, methods and other special pro-

grams. Incentives are an excellent example of a short-term program. Many companies are now re-examining their incentive programs from the standpoint of the return versus the effort expended. This type of effort usually takes considerable manpower on a continuing basis and results can be apparent in days or weeks.

2. *Effort directed towards improving the present system* either through better balancing, changes in layout or tooling, and development of special equipment. This takes smaller but higher skilled effort and results are usually obtained in a matter of months.
3. *Analysis and development of entirely new systems* to get the job done plus re-evaluation of objectives and direction. This requires a very small but highly skilled effort working for long periods to achieve results which may not be realized in less than three to five years. It is in this area where some of the greatest payoffs in increased productivity lie.

The above points, at first glance, may appear obvious. But, I wonder how many companies have evaluated their effort in terms of dollars invested in these three areas versus what they are getting or expecting in return. In effect, this is a problem in the allocation of fixed resources because in no period of time will the staff function ever have as many people as they think they should. This I consider healthy, but it also raises the question of whether or not Industrial Engineering, in the past, hasn't gotten some of its black marks due to too much concentration and emphasis in one particular area at one particular level. In many of these areas one can reach a point of diminishing returns at any given time in the life of a business. We must face up to the fact that sometimes the patient does not need work measurement, but a clarification of objectives, an organizational change, or an analysis of this system. It is not hard today to find examples of managements who are looking for quick answers from operations research, in the third area, when what they need is effort in the first area to get a basic cost control system, or, managements who are spending all their effort on maintaining an incentive plan (first area) for a production system which should and could have been junked long ago if a small systems analysis effort had been available.

PLANNING

In planning our effort each year, we take into consideration the potential return from effort at the various levels, and we set our objectives accordingly. Since much of our consulting and special project work comes to us in the form of requests from the President on down to a shop foreman, we allocate manpower to meet these needs. We always seem to have a backlog of these requests so here again is the problem of allocation of effort. This planning of each year's efforts, by the way, is something which starts with each engineer, manager and division superintendent, and is worked over until we have a fairly specific program for the coming year.

When we receive requests for projects, we do not automatically assign them to a particular division, but consider in most cases the individual who could best carry out the specific assignment, give it the leadership necessary, or work best with the department involved. We expect the project engineer to get whatever else is necessary from within the department and recognize that his assignment and obligation is to the department and not any segment thereof. This requires an atmosphere on which the Chief Industrial Engineer must work constantly, because it is only through the application of all the talents within the department, without stopping to tally the credits, that the whole department will grow in stature and recognition.

Most of our projects, at least those requiring more than a man-month or so, and those which cross departmental lines, are handled by teams, with our project engineers heading them up. In most cases these teams are formed by assigning full-time people from the operating departments involved. This practice we have found extremely successful, and we have been following it since 1946. Some of the reasons for our use of teams are as follows:

1. It makes the requesting department or departments involved feel that they have a stake in the definition of the problem and its solution. This naturally "reads" the department in, from the start, takes away the fear of surprise, and makes the findings much more acceptable and likely to be installed in their original spirit.
2. It provides training in the Industrial Engineering approach to operating men, and it often gives them an entirely different and broader viewpoint of their operation. Not very surprising is the fact that most of the men who have worked with us on projects have had promotions following completion of a project. We naturally gain through an increase in the acceptance and understanding of our work.
3. Their use keeps the manpower budget of the Industrial Engineering Department down and preserves a nucleus of high level skills. Familiarization time, if the engineer is new to an area, is shortened and a direct and informal channel of communication is established with the operating group.

When necessary to augment our effort or bring in special skills, we do not hesitate to recommend the retention of outside consultants.

PROJECTS

Assuming that we have a request for a project, either self-initiated or from an operating department, how do we go about organizing and getting it off the ground? Well, for any project of consequence, we require the project leader to develop what we call an approach outline. It is really more or less of a check list which enables the man who is going to do the job, the supervisor who is responsible for getting the job done, and the department manager, to be sure that there is agreement on purpose, scope, approach and timing of the effort.

In assigning a project to an engineer, we very seldom accept the requester's purpose as is. In fact, in most cases we ask the project engineer to discuss the purpose and its background, and to get a feeling for it before he establishes a written purpose and fences it in with a written

scope. I cannot emphasize this preliminary effort in clarifying the objective of the study too much because in many cases we find people requesting a study where what they want or need has not been clearly thought out, at least not thought out as well as it can be before the study is initiated.

There are many times when we are asked to conduct a study when in our opinion what is necessary is a decision, action or effort in another area than indicated by the requester. We have turned down requests for establishing work measurement programs in certain areas because we did not think the effort worth the possible return in actual manpower savings or production. I would like to stress the importance of having something like the approach outline or project plan on every project. I have seen it mean the difference between a successful or unsuccessful effort, and save long projects from cancellation or getting off the track.

As to the mechanics of assignment, my staff and I generally discuss the selection of the project engineer when any question arises. The superintendent, project engineer and I hold a bull session on the project before the project engineer starts on his approach outline. Upon completion of his approach, which now has our approval, it is forwarded to the department which requested the project, for its approval. The division superintendent and field managers review the project status periodically with their engineers. However, no regular or formal reports are required unless they are spelled out in the approach outline. A report of the status of all projects is forwarded to my office once a month.

A project engineer can, and does, discuss his project with anyone in the department, as he proceeds. When he is fairly well along, he prepares a draft of his report. This is reviewed by the superintendent involved and, it is discussed with my office. At that time, the matter of presentation and organization is discussed rather fully because we feel that too many Industrial Engineering efforts fail due to improper presentation. Our practice is to provide the using department with a brief report plus a visual presentation. In most cases the engineer has a set of flip charts prepared for the presentation. On most projects a complete dress rehearsal is held, because we have found that it takes all of our best efforts to assure that the presentation is beamed towards the man who will be seeing it and taking action. In the rehearsals, we find that the contribution of people who are seeing the project for the first time, and who have entirely different interests, are most important. It is only natural that a project engineer, who has lived with a project for months, often misses the forest for the "trees" in translating his findings and recommendations to management people.

IMPROVING THE EFFORT

A Chief Industrial Engineer, if he is worth his salt, will see to it that part of his department's efforts are spent in finding ways to improve the effort of his own department. This not only means the training of engineers, but the planned search for simpler ways to measure work or quality, plus the application and development of new tools and concepts. We have found that this search for better ways to do the Industrial Engineering job just can't be left to chance. This is why we establish projects within the department for the express purpose of improving, simplifying, or developing new professional tools.

Probably one of the easiest ways for a Chief Industrial Engineer to improve his department's output is to be sure his effort, tools, and approach are related to the job in hand. How often are we guilty of using the micrometer when a six foot rule will do the job, or vice versa?

In trying to improve the effectiveness and value of his effort to the company, I feel that the Chief Industrial Engineer must, from time to time, consider what activities to keep and what to give away. Any department or profession, as far as that goes, gives birth to many routine activities as it grows. If these routine activities absorb too much of the time and emphasis of the engineers and supervisors, growth is naturally slowed.

We have developed a philosophy of turning over any activity, regardless of whether or not it comes within the definition of Industrial Engineer, to the operating departments when it becomes repetitive and routine, or where the administration of it will keep us from developing higher skills or responsibilities. For example, we have recommended the formation of methods groups in the Operating Base to take care of much of the methods work so that we could develop our skills in systems analysis and those problems which involve more than one department. At one time, we had the responsibility for completely developing the functional specification and layout of new facilities. After establishing the practices and standards in this area, we have turned it over to facilities planning groups in other administrations and our Facilities Department. They know we are available if they need help.

GENERAL

There is much in the literature today to confuse even the most level headed and experienced engineer. Here is where I think the Chief Industrial Engineer must help his engineers realize that the most important thing they have is their organized approach to problem solving. They should not develop an inferiority complex because they can't read the mathematical jargon in current literature or are not proficient with one of the new techniques. We probably have done as much work in these new fields as anyone, and we are finding that techniques themselves are not as important as the ability to see applications. In fact, many of the techniques are not providing new solutions but are forcing us to think more deeply about some of our old problems, and in some cases, to increase

our understanding and change our attitude as to what's possible and what's important. As far as we are concerned, the best over-all professional performance will be by those engineers who know the limitations and areas of applications of these modern techniques, rather than by those who are extremely proficient in their use.

Most Industrial Engineers today realize that their profession is going through a very trying period, and that their actions today may well determine the ultimate stature and role of the entire field. We feel that the profession's full stature will only be recognized if we concentrate on the development of general practitioners, skilled in the diagnosis of an industrial system's ills or strengths, along with the development of specialists or technicians who may be called upon for consultation in working a cure. I feel it is the job of every Chief Industrial Engineer to develop these general practitioners, because it will only be through them that our professional status will be established. Let's not become so involved with the new techniques, as we did with some of the old, that we miss the boat. One never becomes a professional man if he becomes so enamored of the tools and techniques of his profession that he loses sight of the prime objectives.

Another thought I'd like to share with you has to do with maintaining the *esprit de corps* and service attitude of your department. Whether we like it or not, we're a staff function, with the job of helping management and the line managers do a continually better job. In most cases we represent change in areas where the line manager considers himself a professional, as he is, and where without his acceptance little gets done. Most Industrial Engineers, in winning acceptance and confidence, bend over backwards in giving the "line" credit for results. Your job, Mr. Chief Industrial Engineer, is to recognize, internally, the engineer's contribution and to encourage this service approach.

I'd like to close my presentation with this observation. The Industrial Engineering function in a company is, in reality, its research and development effort—dealing with the whole management and productive process. In managing this type of function, the Chief Industrial Engineer must realize that he is not running a shop, but that he is directing a Research & Development effort which must be continually evaluated, balanced, and improved.

Making Industrial Engineering Pay Off

by **DOUGLAS WATSON**

Principal, McKinsey & Company, Inc., Management Consultants

As a logical follow-up to the material presented at the earlier sessions of the Chief Industrial Engineer's Forum, I propose that this subject of evaluation and control of the results of Industrial Engineering activities be approached from the "project" point of view. My purpose is to tackle some of the problems involved in making Industrial Engineering work more effectively. I will touch only briefly on internal procedures in Industrial Engineering, and organization of the Industrial Engineering function. But, within the framework of Industrial Engineering, I would like to discuss how Industrial Engineers can do a better Industrial Engineering job—for it is only in doing a better job that we can make our work really pay off in full. And I have the feeling we are not doing as good a job as we can and should.

TWO PROBLEMS

This subject can be broken down into two parts. The first is essentially internal—how do we get better control over Industrial Engineering work? The second is external —how do we get management acceptance of the Industrial Engineering function, and in particular, the results of Industrial Engineering projects? Basically, our problem is: We have a good product, but unfortunately, it isn't selling as it should.

Let me give you two examples to illustrate why I think Industrial Engineers should be concerned about the function they perform and its acceptance by others.

Recently, one of the large primary metal producers and fabricators in this country went through a drastic staff reduction in an effort to reduce overhead costs. As part of this reduction, they virtually discontinued the Industrial Engineering function. I submit that a management which recognizes the worth of the Industrial Engineering activity will fight to make it one of the last, not the first, overhead groups to be eliminated. My second illustration comes from a smaller company in the graphic arts industry. Here, the Industrial Engineering activity made a fine start. But, after several years, it dwindled in importance because it couldn't demonstrate, to management, an ability to return tangible benefits to the company.

Whenever a questioning attitude exists on the part of management, the two basic problems cited above come up again and again. Industrial Engineers are not doing as well as they should in controlling their own activities. Even more importantly, they are not as effective as they should be in getting management's enthusiastic acceptance of their work.

This is both a real challenge and an intriguing opportunity.

CONTROL REQUIRES PLANNING

Let us examine the first of these situations: How do we evaluate and control results of the Industrial Engineering team? One of our primary problems here is in our own attitude toward the work we do. We seem to take one of two extreme views: either we see the Industrial Engineering project so clearly that we think we don't need to establish a project plan for it; or we see it as such a sub-

stantial project that it seems we spend more time planning for the project than we do in executing the plan.

Neither viewpoint is very realistic. From my own experience, there are few Industrial Engineering projects so small that they don't warrant setting up a basic project plan. Even the large and complicated ones should have a project plan that is simple, straightforward, and provides the basis for control over results.

Even though you are all familiar with the elements of a project plan, it may be helpful to mention them again.

WHAT ARE WE WORKING ON?

If we are to talk about an Industrial Engineering project, we need to have a title and a reasonably clear description of it. We ought to reduce the title and description to black and white and set them up on a project plan sheet so that we can discuss them with management, as well as with others in the Industrial Engineering department. Incidentally, right here is where we can save much time, if we have a good clear description of what we are trying to do. All too frequently, misunderstandings at this point result in many lost man-hours and unsatisfactory results.

Early in the planning stage, we should also describe the anticipated results. This description should be in terms management can appreciate—measurable results, which should be tied in to existing financial reports or data for support. Describing the anticipated results will help substantially in preparing a realistic statement of the scope and extent of the project.

WHAT IS OUR SCHEDULE?

After the title and description, the next step is to define the project with its proposed component parts, establishing a tentative schedule for their accomplishment, and developing a reasonably detailed manpower budget for each of the schedules.

Estimating a manpower budget is one aspect of project planning where experience in the consulting field is perhaps more helpful than experience in an Industrial Engineering Department. The nature of consulting work forces us to identify the individual consulting projects or engagements on which we work, and to break them down into their important component parts. We find that this is the only way we can determine the magnitude of a project ahead of time. This is essential, both for our own planning and for our clients'.

WHAT PROGRESS ARE WE MAKING

In terms of procedure, our appraisal of project progress starts with the way we record our professional time. Whenever possible, we identify the time spent in such a way that we can check back to our manpower budgets. This is where the control starts, but, it is only part of the story. You can't measure an engineering team's progress solely by the clock.

There is no substitute for close, personal supervision when evaluating the success of creative engineering projects. Someone, usually someone not involved in the day-to-day team organization, should review the work the team is doing and gauge the progress being made. Here again, experience in the consulting field may be helpful. Because of the type of work we do and the professional relationship we have with our clients, we are constantly reviewing our rate of progress. For example, we usually bill our clients on a periodic basis. When we prepare our statements for professional fees, we analyze the work done and its value to the client. This provides an excellent opportunity to measure the consulting team's progress on the project.

Many of the same control techniques that we use can be applied also in industry. As an indication of the extent of this sort of supervision and project follow-up in our work, we feel that a member of our management group should have no more than four to six consultants working with him. Only in this way can he devote enough time to reviewing the various projects to satisfy himself that progress is made.

Needless to say, there are some parallels to this outside the Industrial Engineering profession. Those of you who have had an opportunity to study the problems of research and devolpment can see many of the same control problems emerging there. The most successful companies in this field follow essentially the same procedure. They define their project, they lay out basic project plans, and they review them frequently during the course of the project work.

One of the by-products of this sort of review is, of course, that it permits the change of project plans as unexpected developments occur, either in the project *per se* or in the management attitudes toward it. It would be presumptuous to say that it is possible to establish a detailed project plan at the outset of a study, and to have that plan apply over a course of many months. We are turning more and more to the use of a diagnostic study to establish the basic project framework. This helps us, not only to identify the problem more clearly and get management's acceptance of that definition, but also, to establish the area where we will need to probe in depth.

CONTROL REQUIRES FOLLOW-UP

Follow-up is essential to effective control after the project is completed.

We have talked, so far, in terms of follow-up during the course of a specific study. It is important, upon the completion of a project, to evaluate the performance of the whole team.

A post mortem of this sort is a very effective training device, for both the project leader and for the individual members of the team. It also facilitates reporting the results of the entire work to management. In our own situation, the end-product frequently is a report to our client

summarizing the work done and the benefits he has achieved.

One aspect of follow-up that I feel is frequently neglected is a periodic audit after completion of major projects. Engineering teams have been known to become disenchanted with a specific project, and upon its completion, to chafe to get on to greener pastures and newer projects. One by-product of this attitude is an inclination to ignore the work already done, even though much can be learned by going back and checking or auditing the results of previous studies. The Industrial Engineer should not fear continuing change, which I am sure he will find if he takes a look at his work of last year and the year before. Such a look back affords a logical and worth-while opportunity to up-date study results and make his work even more valuable to management.

At times, it is indeed revealing to review the recommendations on a project where the anticipated results have not materialized. As Industrial Engineers, we ought to be perfectly willing to chalk up our box score and learn from each of our projects how to do the next one better. Every time we look objectively at past work, we improve our ability to judge the effectiveness of our work.

INTERNAL CONTROL IS ONLY PART OF THE JOB

Doing a better internal job is only a small part of making Industrial Engineering pay off. A bigger part of success comes from gaining acceptance of our work by operating managements, and from getting Industrial Engineering benefits recognized by top management. Only when all levels of management recognize the values inherent in Industrial Engineering work can we expect the Industrial Engineering function to grow in importance and become more worth while.

This is another case when our own attitudes may be giving us trouble. All too often, Industrial Engineers take the position that Industrial Engineering work should stand on its own feet—"let's let the facts speak for themselves." The horrible part of this position is that at times we find we were standing on shifting sands and, too late, we realize, with a sinking feeling, that the things we thought were facts weren't really facts at all. We ought to recognize that we deal with human beings, semi-facts, and opinions, and we must do more than be merely "objective." We must recognize that the success of Industrial Engineering work is measured in management's responses, and *not* in ours. We must recognize that superb technical work is not enough. We must accept the fact that only when management believes in the results of Industrial Engineering work, and expresses its confidence by adopting our recommendations, does our work pay off.

ACCEPTANCE REQUIRES GETTING PEOPLE TO CHANGE

What do we need to do to improve our batting average in gaining management acceptance? Because almost every Industrial Engineering project proposes change, and the only real pay off is when this change is actually and effectively adopted by management, we should recognize that our problem is also one of getting people to change, not solely one of developing the facts.

Here, the Industrial Engineer can really contribute much more than he has in the past. We must learn to conduct our Industrial Engineering activities in such a way that the people with whom we work will accept change, and will change basically as a result of our recommendations.

From my experience there are several things we can do to encourage this.

A REPORT IS NOT ENOUGH

We should recognize that the best designed plan or proposal will not make its own way. It needs to be helped by management acceptance, and by the acceptance of the people who will have to make it work. This means that management must be kept constantly aware of the benefits of Industrial Engineering work. This requires a continuing job on the part of the Chief Industrial Engineer.

The desks of American management are filled with engineering reports that have not been adopted. This is one of the reasons why we prefer to submit reports as a confirming document after acceptance of the project recommendations. We will have the study well documented before presenting our recommendations, but we do not rely on this documentation to "sell" the study results.

Constant liaison is needed between the study team, the operating management, and the top management of the company. Using this approach, management is brought along with the project and is not forced to "study" a detailed report. It is unfortunately true that the written word cannot be relied upon to convey the whole engineering story.

OUR APPROACH MUST BE RIGHT

We need a "supplement" attitude—not a "supplant" attitude. We must conduct Industrial Engineering work in such a way that the operating people with whom we work will not suspect our motives. As soon as they do suspect our motives, we have raised a barrier to acceptance of Industrial Engineering work that is particularly difficult to break down. Industrial Engineers, by casting themselves in the role of being a help to operating management, not an end in themselves, can do much to allay the suspicion that frequently surrounds much Industrial Engineering work.

THE JOINT VENTURE ATTITUDE

We can learn much from the psychologists in this area of getting acceptance of our recommendations. For example, we should recognize that involvement of operating management in Industrial Engineering projects and, if

possible, practice on their part in implementing the problem solutions are essential for enthusiastic adoption of a new idea.

If we accept the fact that the result of almost any successful Industrial Engineering project will require a change in individual behavior, then perhaps a checklist of the things needed to gain acceptance of a new idea or proposal can be helpful.

A CHECK LIST FOR IDEA ACCEPTANCE

When we want to get people to accept a new idea, and essentially change their way of doing things, we must recognize that there are many things that inhibit this process. Adopting a new approach is always dangerous and, as a corollary, doing things the old way is usually fairly safe.

If we are going to be most effective in getting others to adopt our recommendations, we should ask ourselves these questions, and work out satisfactory answers to each of them:

1. What changes in management and employee behavior are we asking for?
2. What preparation need we make for the new responses we expect from management?
3. Have we provided motivation for these new responses?
4. Is the new response being rewarded or will it be?
5. What responses need we eliminate?
6. Have we removed rewards for the old responses?

While these are fairly simple questions to ask, I think you will agree that they may be difficult to answer. However, if we will examine our major projects from this questioning point of view, we can raise our batting average. This is the Chief Industrial Engineer's job. If he will also concern himself with the management climate surrounding his work in this constructive way, he will insure that all levels of management will be more enthusiastic about Industrial Engineering and the results of Industrial Engineering work.

SUMMARY

In summary, then, I suggest that in handling the Industrial Engineering project we do these things:

1. Structure the study for particular activity or involvement by those people who have to carry out the recommendations.
2. Anticipate the personnel problems of acceptance of, and action on, our recommendations.
3. Where necessary, provide "escape-hatches" for management to retreat from previous positions.
4. Develop proper relationships with operating personnel, at the action level, so that they understand our point of view and do not suspect our motives.
5. Solve the problem of taking credit for these recommendations by recognizing that staff activities, such as Industrial Engineering, do not make savings—they help others make savings.

These steps will help us accomplish the two things essential to making Industrial Engineering pay off:

First to improve our internal control so we do, and know we are doing, a better job. This requires careful planning, including defining, describing, and budgeting the job; and a consistent, tenacious follow-up to evaluate past results and to give us the full benefit of our own past experience.

Second, to gain better acceptance for our work. This inevitably requires getting people to change, and dictates unflagging effort toward improving our skills in working with people.

By deliberate and conscientious attention to control and acceptance all of us can help increase Industrial Engineering's already substantial contribution to effective management.

The Industrial Engineers' Concept of Productivity

Productivity in Electronics Manufacturing

by **R. B. PARKHURST**

Vice President, Manufacturing, Hughes Aircraft, Los Angeles

IN TODAY'S complicated world of industry, with the great stress placed on mechanization, organization, electronic computers, and business machines of all types, we often overlook the simple fundamentals and principles that were responsible for our achievements. One of these principles, which has been of great benefit during the years and which has helped our company achieve considerable success, is: "Change, Based upon Principle, is Progress; Constant Change, without Principle, is Chaos." Another principle is: "The Visual Control Flow of Material Through Men and Machines." This is the basic principle of production. Both of these simple principles must be applied, through supervision, in order to achieve an orderly and successful company growth.

The greatest factor contributing to a continuing growth and strength within our company is the manner in which people work within our plants. We are all striving for a high quality product, with greater production at the least cost. Achieving these, we strengthen our competitive position, and we are assured of job security.

INDUSTRY DEVELOPMENT

Comparing our new electronics industry with the automotive industry, it is quite apparent that the automotive industry has had many years to perfect and "bed-down" their production principles. We are an organization in one of the fastest growing industries in our country today. It is our basic problem to apply sound production principles so that we may continue to be a strong competitive company within a rapidly growing industry.

OBJECTIVES

The objectives of our company are very sound. We are striving for greater progress in research and development and to improve the reliability of our products. We are working to conserve material and labor and have good employee relations. The fulfillment of these objectives to the greatest degree possible will add strength to our company and insure our leadership in the electronics industry.

Many companies in the electronics industry have not expanded in the same orderly manner that we have. They seem to have grown, to some extent, like "Topsy," and as production increased, they have added to their facilities each time that an emergency arose. There is no surer manner of defeating growth and weakening a company than with this type of expansion. "Built-in inefficiency" is such that even the best of supervision cannot cope with it. In the long run, these companies will become one of those hundreds that will fall by the wayside.

PROVIDING FACILITIES

During the past few years, many companies have recognized a very definite responsibility for providing facilities that lend themselves to "built-in" efficient operations. After top management has provided this facility, it is production supervision's prime responsibility to operate the plant such that the greatest yield can be obtained from the dollars invested.

To gain the greatest yield from dollars invested within the plant it must be recognized that all production is the result of the expenditure of some form of energy. Within the plant there are two major sources of energy: first, that energy in the form of heat, light, gas, power, etc. This is well controlled and we know from day-to-day exactly the amount used and the cost to our company. But, plants have no productive output without the greatest energy of all—and that is human energy. This human energy enters our plant each morning and leaves each night, and it is what we do to control this human energy that is the basis of my talk. All other energy in this modern day is thoroughly controlled, but the control of human energy, both mental and physical, is one of today's greatest problems. A person will expend more energy working inefficiently, in one day, than efficiently. The only control we have over the efficient use of this human energy is the manner in which we provide well planned facilities and supervisory ability to direct this energy toward greater productivity.

TRAINING FOR PRODUCTION

Our people are recruited from all walks of life. We must train them in the manner in which we want them to produce so that they become a hard hitting team for the design and building of our products. They are our greatest investment and our greatest asset. We invest approximately $8,000 per employee, on the average, in facilities, machine tools and equipment, so that each and everyone may do a day's work.

Why is the human being important? Figures show that an average production hour consists of 30% machine time and 70% manual time. I know that many of us are proud of our machine tools and feel that if we could only buy more automatic equipment, or other labor saving devises, we would increase our production and improve our competitive position. But let's see what actually happens to a productive hour within the average manufacturing enterprise. Let's take the 30% machine time first. The machine is purchased and is the result of technological achievement of the machine tool builder. However, we all understand that our competitors can buy these same machines, so the 30% is generally a common level of machine performance throughout all companies in a comparable business. But to get back to the 70% manual time, that is where we as individual companies have a great opportunity to improve our productivity. This 70% can only be controlled by our own management and supervision. It is something we cannot buy from others. So, it is the degree in which we can improve this 70% that will greatly reduce our cost and enhance our competitive position in industry.

Your company, and mine, is in business to manufacture a product, and all production is produced at the working level. The organization, from the General Manager to the department heads, is there to support the supervision at the working level, and provide the monies and policies so that the supervision at the working level can do an effective job. If this is true then, the most important people in an organization, *from a competitive point of view,* are the Foremen and the Assistant Foremen. They are the ones who directly supervise the majority of our people and are responsible for the spending of our monies. They spend at least 80% of all the monies provided by the company. It is obvious that the success or failure of a company largely rests on how well they are equipped to do this important job.

With the proper utilization of human energy, a plant can be run 100% effectively. But, many companies operate at a level of 50 to 70 percent effectiveness. This is the great difference between a blue-chip company and one that is growing like "Topsy." Either of these results can be obtained from the same investment in men, materials, and machines.

As the people leave your plants at the end of the day, have they expended their energy in a fully constructive manner? If they have, you will have a very successful company. They in turn will feel a personal pride of accomplishment, which is the very foundation of every man and woman's happiness and growth without frustration but with an enthusiasm for the next day's work.

Productivity in the Airframe Industry

by **THOMAS L. McCARTHY**

Director, Master Programs and Analysis, Northrop Aircraft, Inc.

THE environment in which most members of the airframe industry find themselves today, illustrates how the customer runs his total enterprise and how he utilizes Industrial Engineering techniques in the comparison of the individual contractors. My presentation will indicate one method by which airframe management can cope with the situation and compete in the future.

THE INDUSTRY

Since the early 1950's the total employment for the airframe industry has risen considerably, but not to a degree commensurate with the increase in government defense expenditures for airborne and related equipment. This lack of proportional growth is doubly significant when one considers the increased cost of present weapon systems as compared to those of previous years. An appreciation of this increased weapon system cost may be gained by the fact that it took twenty-five times more engineering man-hours to design a recent multi-jet bomber than the World War II bomber which it replaced.

If the airframe industry had continued to expand and develop the multiple capabilities required to produce today's modern weapon systems, a growth in total employment of 1,100,000 people would have been experienced compared to the growth of 600,000 people actually experienced. The increased complexity of today's weapon systems has encouraged the development of concerns specializing in the fields of Weapon Systems Management, electronics, processing, and propulsion. Therefore, the growth factor caused by the increased Department of Defense expenditures has been experienced jointly by these concerns and by the airframe industry. Airframe contractors have been forced to increase their engineering and scientific personnel in the fields of weapon systems design, including electronics, propulsion systems and weapon systems management, in order to have the capability of successfully proposing and managing new weapon systems for the strategic needs of the Department of Defense.

The individual airframe contractor exists in an era where it is becoming increasingly difficult to compete in the entire spectrum of defense needs. The spectrum extends from the simplest primary trainer to the most sophisticated boost-glide space vehicle. It is apparent that the contractor must select fewer product areas in which to specialize and compete, plan his destiny in these fields of endeavor, develop the most competent team of design and production personnel, and develop through manufacturing research the advanced machinery required to handle the new exotic materials, in order to obtain the most efficient facility complex that can be devised for the chosen spheres of activity. Furthermore, this specializing of capability not only increases the contractor's competitive position as a prime contractor, but is indicative of the prime contractor's trend toward "associate contracting." This is the banding together of *two or more* prime contractors with complimentary capabilities in a joint attempt to design *one* weapon system. To achieve productivity in this climate is today's challenge to the Industrial Engineer.

THE CUSTOMER

For purposes of this discussion we will assume that the customer is the Department of Defense. Certainly he has his problems too; many of which are similar to ours. His paramount task is to keep our nation secure in all eventualities. He must understand potential strategy which might be used against him and devise counter-strategy and weapon systems which will give him the greatest possible advantage. He has limited funds and must bear with political requirements that perhaps transcend other considerations. Because of this combination of factors, he has had to narrow his activity to a few, scientifically chosen weapon systems. His allowable margin of error is minute.

In the case of the Air Force, the Using Commands and ARDC provide the primary inputs which initiate research and development programs, which in turn eventually result in the production of new weapon systems. Based on expressed requirements of these agencies, the contractor's task is to create, invent, and conceive devices and/or systems which will provide economical and timely solutions for defense needs. His proposed solutions must represent the highest degree of excellence in order to successfully obtain the business, because for reasons already stated, competition has become increasingly keen.

PLANNING REPORT

For the Department of Defense to efficiently run a 40 billion dollar per year enterprise, it is obvious that he must utilize to a very high degree the most effective Industrial Engineering theories and practices which research and industry have devised. The phase of the customer's Industrial Engineering with which airframe contractors must cope is well summarized in the Aircraft Manufacturer's Planning Report, commonly called the A-M-P-R, or "AMPER" report. This report presents in

summary form various indications of customer efficiency and productivity in comparison with other contractors and with the industry as a whole. Some of the significant indices which are reported upon by the AMPR system are:

1. *Pounds of product produced per square foot of factory area.* Here the contractor's ability to efficiently utilize his facility by relating a common denominator of production—pounds of output—to square feet of factory area is measured.
2. *Hours of direct labor expended per pound of product produced.* Here the contractor's ability to efficiently utilize his manpower resources by measuring input (hours) versus output (pounds) is measured.
3. *Direct to total personnel ratio.* Here the "mix" of personnel that the contractor has employed is measured. A severe imbalance could indicate serious production interruptions in the future.

By the use of these and other indices, the Air Force judges the competence of each of its contractors. As these judgments are applied on a consistent basis to all contractors it can be stated that they truly represent, particularly in the productivity indices, the comparative quality of the contractor's design, planning, tooling, facility effectiveness, and cost control techniques.

At this junction it might be well to point out that the AMPR indices should not be taken at face value but rather should be the subject of critical analysis. For example, if a contractor rates high on the direct-indirect personnel ratios it may indicate a lack of sufficient effort devoted to product development. Similarly, a contractor could be performing well within his negotiated costs and will rate poorly on the productivity indices. This is often the case during the early stages of a production program or when a product advances the state-of-the-art by utilizing new production processes.

The point is that the AMPR ratings should also be analyzed in the light of other measures of contractor efficiency such as schedule compliance and cost performance.

Certainly your managements (if you are in the airframe business) have had the disquieting experience of having internal reporting indicate on-schedule cost and performance, and at the same time receive biting criticism originating from the customer's Industrial Engineering section indicating a below industry average performance in some AMPR indices, probably the direct-indirect ratios. And perhaps you have been in the same situation in which I found myself recently—that of burning the midnight oil in determining rationalizations for these apparent opposite indications; and you probably found, as we did, that the predominant answer lies in the product "mix" of business at hand, or the ratio of research and development to production type work.

Predicated upon the customer's Industrial Engineering concept of productivity, it is quite obvious that management must achieve a proper balance between those programs which are in production generating significant pounds of hardware, and those programs which are in the research and development category, which will produce significant pounds of hardware some years hence. To obtain this balance the contractor must organize and devote a great deal of his management resources to this endeavor. It will not happen by itself. There is little luck involved in successfully obtaining a new weapon system contract.

LONG RANGE PLANNING

How does a contractor plan to obtain new business? First, he must have the capability for devising new products in consonance with the projected needs of the Department of Defense. He must have a system for timing the development and introduction of these new products into his industrial complex. This system, in total, is called long range planning. Assuming that we have the capability to devise acceptable solutions for defense needs, we must organize—and manage—in order to make decisions now that will lead to the proper implementation of production programs five years hence. It is in this area that the Industrial Engineer is uniquely qualified to render the greatest service to management. He must interpret the engineering description of the future product in terms of complexity, tooling concept, materials, production techniques and processes, and advanced facility and equipment requirements. He then must recommend to management the direction it must take, and then control the development and expansion of capabilities in specialized areas such as chemical milling; ceramics; automated machines; high temperature bonding; specialized assembly processes including such things as the brazing of stainless steel honeycomb sandwich structure; and advanced data processing. The Industrial Engineer is responsible for translating management's product goals into the capability for producing products of the future, economically and with minimum lead time.

For the Industrial Engineer to perform his task in such a manner that increased productivity will result, timely decisions must be made. These management decisions are not those of the line supervisor, but rather those of top management who have the ultimate responsibility to the Board of Directors for achieving consistent profit on operations and expending capital funds in a manner consistent with company goals.

SUMMARY

Our task in the airframe industry is to maintain the ability to conceive weapon systems that will provide the Department of Defense with a strategic advantage.

Our Industrial Engineers must create the production technology that will assure the availability of modern machinery, equipment, processes, and facilities consistent with the ever advancing state-of-the-art.

Our management must make long range decisions which will guide the Industrial Engineer and assist him in the Titanic battle to overcome increasing costs and

complexity, and achieve increased productivity.

We must admit, however reluctantly, that the customer's Industrial Engineer, through the AMPR system, has and will continue to increase the productivity of the industry as a whole.

Productivity in Light Manufacturing

by **W. H. TRUMBULL**

Vice-President, Paper Mate Manufacturing Company

THE Ball Point Pen business is only eight or nine years old. The Gillette Company purchased Paper Mate at the end of 1955 at which time I personally moved from razor blades to pens. Consequently, I will be talking both about razor blades and about pens. However, as I am sure we have all found, the same manufacturing principles apply regardless of the product we are making.

We all must produce our product at the lowest possible cost. There are many factors affecting cost, including materials, labor and overhead. I would like to limit this discussion to reducing labor cost or to increasing the productivity of labor. And, when we say labor, I am talking about both direct and indirect labor. (As a matter of fact, I have never known why we, as management, insist on breaking down labor as direct and indirect. To me, it is all labor and should be treated as one lump figure.)

In any case, what are the two most important factors in increasing productivity and thus reducing costs?

1. Find and install the most capable line foreman you can.
2. Establish a good measure of productivity.

If we do these two things successfully, the rest will be easy. Tremendous attention will be focused on the productivity index all the way up to the president, and even the board of directors. When attention is concentrated on anything, solutions and improvements will be found, and good first line supervision will carry through a program to increase their department's productivity with resulting labor saving all through the plant.

HOW DO WE GET A GOOD FOREMAN?

One of the most under-rated persons in American Industry is the foreman. Somehow, the word "foreman" conjures up a vision of the old bull of the woods supervisor and yet, to me, the foreman and the foreman alone controls costs. Sure, we have engineers, Industrial Engineers, cost accountants and analysts and other staff men by the score. But, if costs are to be controlled effectively, the foreman is the guy who is going to do it. He's the top-sergeant and you don't win wars without them.

You may say that so-called middle management plays a part in effective cost control. They do, but only for the short term, filling in the gap while the organization at the foreman level is strengthened. The main reason so many companies attempt to control through Top or Middle Management is that there is a gap in the foreman ranks and they aren't doing anything to correct it; with the result being that their own effectiveness suffers since it takes ten times the effort and cost to get an ineffective foreman to do (and then he usually doesn't do it) what an effective foreman will do automatically.

We are concerned with the position in which the average foreman in industry has been placed. We are concerned that despite all the talk, despite all the literature, all the supervisory training programs, all the AMA Seminars, the average foreman today is simply a dressed-up foreman of twenty years ago. Effective cost control and effective *management in a plant* starts, and for my money, ends at the department level. Oh yes, there's a place for management at the top, but if you have successful management at the bottom, you don't have much left to manage. You don't need staffs which have grown up over the years, oh so uneconomic and ineffective substitutes for effective management at the bottom! *We are carefully and systematically appointing managers at the departmental level.* We are prepared to pay these managers well to manage effectively. We are not worried about the argument: "How do you keep good men satisfied at the foreman level?" We know, and you know, that the real problem is to find and develop the men.

How can a real manager be frustrated or bored because of closed frontiers when within his department he is held responsible and given the authority to manage in all the following varied phases of his business. . . .

1. Personnel
2. Safety
3. Scheduling
4. Quality
5. Maintenance and repair of Process Equipment
6. Product, Process and Industrial Engineering Applications
7. Technological improvements, design of product or process
8. *Participation in Overall Company Policy*

If you are ready to pay these men for their accomplishments and are ready to delegate full responsibility and authority to them for the management of the department, subject to a very slight coordination from the top, you don't have to worry about closed frontiers. Frontiers have been closed to the exceptional foreman in his job because managements have talked out the side of their mouth about the foreman's importance, while out of the other side they have been restricting his managerial responsibilities. All kinds of staff are ineffectively trying to do the foreman's job. It follows that management has also restrained the economic outlook for the foreman since it is really thinking in terms of the foreman of twenty years ago, the law of supply and demand, and there's a million like them, so why pay more?

MANAGERS

I am talking about a market where the supply is limited and it follows that the price must be high to satisfy

this apparent blank in the horizon. The price is high—yes, but the returns make the investment read like the DuPont Story. So, we are in the process of calling foremen managers, letting them run their business as managers, and paying them as managers.

Where do we get a good foreman? One of the best places to find a good foreman is the Industrial Engineering Department. We have had extremely good success with Industrial Engineers running line departments. An Industrial Engineer who has proven his ability to handle a foreman's job has far more value to the company than he had as a staff man.

Another good source for a foreman is the college campus. We get trainees with almost any undergraduate major and after 6-18 months, make them foremen. This separates the men from the boys. The day of taking the best maintenance mechanic and making him a foreman is over for us. This may sound as though we do not promote from within. We do promote from within, but a good maintenance mechanic who is worthy of promotion should be trained in some other capacity before he is given one of the most important positions in the plant, that is a foreman's job. In most cases, when a mechanic is promoted to foreman you make a bad supervisor and lose a good mechanic.

STANDARD COSTS

Now, let's look at the second point—that of developing an index of productivity.

We have an elaborate system of standard costs in all the Gillette factories. These Standard Cost Books are wonderful for the accountants as they can quickly close the P. L. statements and balance sheets every month. But as an effective means of controlling costs in our plants, the Standard Cost System is practically worthless.

Try to convince an accountant that this is the case. If you can, by some ingenious arguments convince the accountant that you haven't got quite what you want in the way of cost control, he will come back at a later date with some additional figures. He will have an additional number of variances such as variance due to volume vs. variance due to inefficiency.

Frankly, I do not like variances. Whether they are favorable or unfavorable you still do not know how good a job you or your people are doing. Variances depend on a standard, and depending on how the standard was set you can look either good or bad. Even with a perfectly engineered standard, it is hard to know where you are. Is 105% of a standard good or bad? And in many cases the standards are for one reason or another poorly set.

When I first started work at Gillette, I donned my overalls and operated a screw machine. Besides busting tools and jamming up the machines regularly, I learned some good lessons.

The Industrial Engineers had set a standard on the razor handle of 1300 handles per day. How they had arrived at this, I am not sure, but when I started, we could easily make 1700 per day. Consequently, we would run the machines Monday through Thursday and all day Friday the machines would cut air and we would take it easy. Secondly, if we had down time on a machine and produced only 650 handles per day, we would merely subtract the lost pieces and put it in as down time, in this case, 650 pieces less than standard, or four hours down time. We always operated at 105 to 110% efficiency—not bad.

QUALITY CONTROL CHARTS

Another practice which really has nothing to do with productivity, but which taught me another lesson was in the use of quality control charts. I was not familiar with control charts and the second day I asked one of the operators about the charts and how one filled them in. He allowed as how he didn't know much about them, but that you put three x's every fifteen minutes between the two red lines. Also, be sure not to put all three x's on the same line as this didn't look right.

And to finish the quality control chart, a short time later our Director of Quality Control was showing the eminent Dr. Juran around the plant and pointing with pride at the quality control setup in the screw machine department. The time was about 9:30 in the morning. He picked up a sample chart to show off proudly, only to find that the chart had already been filled in for the rest of the day.

Needless to say, all of these practices have since been curtailed. However, as screwy as these practices sound I will bet that similar things are going on all over the country. *The chief lesson which I have learned is simply that periodically we have to follow up every system which we install.*

ACTUAL SCORE CARD

If we don't like variances and standards, then what do we like? We like an actual score card. We like a ruler which is always 12 inches long. Our productivity measure should be the same in 1975 as it is in 1958. With standards and variances we will still be producing at 105% in 1975. And how will we know how good a job we have done on productivity? The answer is obvious—we won't.

Consequently, our index should deal in terms of hours and units produced. An hour will forever be 60 minutes. We cannot use dollars, as a dollar will not always be 100 cents. In fact, I believe it is currently about 50 prewar cents and judging from our meat bills, I'd be inclined to think that this is overrating it.

What we should have is an actual figure on units per man hour or hours per unit, if you prefer. But, we must go one step further and have only one figure for a product. If we were making motorcycles, we should have one figure for all the motorcycles we make. Maybe there are ten different models, but we still should have one figure

for all models. Then everyone including the president knows that in 1958 we made ten motorcycles per man hour. If we make 11 motorcycles per man hour in 1959, we have increased our productivity 10%. Next, we must give the manager of each department one figure showing his portion of the total even if he is only making one of the components.

PRODUCTIVITY REPORT

Now, let's suppose that the productivity report for a given department doesn't look so good, it's going down or it's leveled off, what are the foreman's reactions? Some months previous, he knew this day was coming—so since he is a manager, he has been planning and pushing the Engineering Department to come up with a machine design change which, with no extra effort, will allow the operators to run two machines instead of one. Or he has already in the past reached the near ultimate in machine-to-labor ratio. He has, therefore, been planning with Engineering a new machine which produces twice as much with the same machine to labor ratio. (Note that I use the term "machine to labor" meaning all labor, direct and indirect, not direct labor alone.) Or maybe he is working with Industrial Engineering on a conveyor setup to reduce handling costs. The foreman is responsible for all such installations. If they are late, it is his fault. If he's going to be held responsible for his productivity and given the credit, he's also going to be held responsible for his lack of productivity. *Since he is getting most of the credit (as do all presidents) for the good things a total group produces, he is also going to get the blame. That philosophy, and that philosophy alone, is the road to greater productivity and lower labor costs.*

PRODUCTION & COSTS

Besides the productivity figure we give each foreman a dollar figure related to production for the cost of repairs, the cost of supplies and the cost of overtime which are also large factors in the total cost picture and they must be effectively controlled. Here again, the manager must exercise on-the-job control. Does this machine need overhaul? How much of the machine needs overhaul?

Woe be the manager who follows the dictum of a maintenance machine shop. The machine shop philosophy goes something like this: we must have *preventive* maintenance. All well-managed plants have preventive maintenance schedules, therefore we will have a schedule. This type of machine will be overhauled yearly, that type over there every three years, this one here every two years. Now it is time to overhaul that type machine and since we aren't particularly busy at the moment, we can take six of them right away. So they take the six machines and strip them right down to the floor. Since they have them stripped to the floor they might just as well replace each part from the floor up *so we won't have to do it a little later on.* Save money that way?

I can assure you that once a gang of conscientious maintenance machinists get going on such a program *(unless severely controlled by the manager)* the cost of repairs will be out of control and you won't need a report to show it. Furthermore, I can assure you that nine times out of ten the machines won't run as efficiently after the overhaul as they did immediately before and will take days of debugging to get them even back to par. With us, the manager decides when a machine is to be torn down, and he never tears one down which has been running efficiently. Except for accidents, there are very few machines anywhere which don't show pronounced symptoms by lack of efficiency before collapsing; and since the manager is held responsible for the cost of his repairs as well as the efficiency of his machines, we leave it to him to decide when and how much repair. It follows then that the manager needs a report as a yardstick, and we give him one monthly in terms of actual repair cost per number of units produced. The same sort of reasoning applies to a supply account and he likewise is provided with a cost of supplies per million good blades.

The chart representing blades per man hour is by far the most important. In the last ten years the number of blades per man hour has doubled which has enabled us to keep costs level and the selling price constant. I can't think of many products which have not gone up in price in the past ten years.

This unit per hour figure has also been used as a comparison among plants. At one time the Mexican factory was leading. At another time, Canada was in the lead. Competition is a great thing and this international comparison of plants, both on an over-all and on an individual departmental basis is responsible for a large part of the increased productivity. The figures can also spur competition between the first and second shifts.

We have also applied the same figures to razor making. Here we have three completely different models. By weighting the various models we have one figure for the whole razor division. Here again, we give each foreman a productivity index based on equivalent razors in his department. Currently, we are working on the same thing for pens, and I am quite confident that this will prove just as successful as the blade and razor indices.

CONCLUSION

To conclude, when we have installed good foremen all the way through and we have given them a good measure of their productivity, we have prepared the way for increased productivity. With a bad foreman, we apply 10 pounds of pressure to get one pound of work with a great deal of wasted effort. A good foreman-manager will take all good suggestions from the various staffs and hound them for further help. He will get you IE's to help him get more productivity. And with a good index, everyone can keep track of the score.

Productivity in Petroleum Refining

by **R. M. BROWN**

General Superintendent of Operations, Los Angeles Refinery
Union Oil Company of California

THE REFINING objective is to convert available raw materials into finished products of a quality and in quantities that can be most successfully marketed. Of utmost concern, therefore, are efforts towards:

1. Matching capacity with demand (where satisfactory outlets exist).
2. Increasing product value (where warranted by realization).
3. Reducing manufacturing costs.

These, then, can be termed the *productivity objectives* and each has a profitability overtone. They are broad targets. Were it possible to assume that productivity lay only in the construction of new automatic machines, or in the ability to increase unit output or to reduce spoilage and waste, or to reduce manpower, or to reduce sick leave, or to improve in any one of a hundred significant but single areas, it would be relatively simple to organize a plan for improvement. But Productivity Improvement cannot be so simply limited. Rather it is necessary to recognize the problem for the many-headed hydra that it is, and continuously attack in many directions simultaneously. Such a multiple and simultaneous effort requires a careful marshalling of available talent. The purpose of this report is to present an outline of one such multi-pronged approach.

Before looking at the makeup of this particular program, let us first consider the results that can be felt to date.

MEASURE OF PRODUCTIVITY

At best, the measure of productivity in refining is illusive. Company profit cannot be considered alone since it may represent the combined efforts of several company divisions. Operating cost of a particular facility can be a dangerous measure since it may reflect product and service demands beyond the administrative control of that individual facility. Similarly, throughput and output comparisons can be misleading since incremental units of production may not be proportional to the incremental manufacturing effort. For want of a consolidated efficiency factor, however, we must at this time resort to traditional units of measure in order to evaluate our Productivity Improvement Program.

Despite a rising refinery cost index of about five percent per year, our total refinery operating costs have actually been reduced ten percent in the past two years. Manpower has been lowered by about twelve percent. Overtime has been cut in half, disabling injuries reduced fivefold, and fire loss lowered to the extent that in one refinery, for example, there hasn't been any loss at all reported in over fifteen months. During this period and until a softened product market forced curtailment of crude runs late in 1957, raw material throughput continued to increase by about three percent per year and product quality, particularly gasoline, skyrocketed. These facts tell us, then, that our productivity is increasing and that our ability to cope with a more intensely competitive climate has been markedly enhanced.

Let us examine in general outline the variety of methods used to approach this productivity objective, keeping in mind our thesis that only through a multi-faceted program, can success be realized. To facilitate discussion these methods have been somewhat arbitrarily divided into four broad categories, namely: *Process Analysis, Mechanical Analysis, Organization and Work Methods Analysis,* and *Operations Analysis and Planning.*

PROCESS ANALYSIS

In the area of Process Analysis it should be recalled that Automation was the keynote of petroleum refining before the word itself was coined. The concept of the automatically controlled continuous process is a refining cornerstone. A typical refinery consists of twenty or more individual and highly instrumented continuously operating process units, each designed to perform a specific portion of the refining job. Intermediate and finished stocks from these various units are transferred to storage, blended together as required, and finally shipped. For the ultimate in productivity, it is necessary to look at the refinery as a whole in the same light as specific process units. Until very recently the concepts of continuity of operations and automatic control had not been applied in the facilities outside of the individual processing units. Our objectives here have only been partially realized, but already with the installation of remote reading automatic tank gauges, remotely controlled flow streams, automatic and continuous blending facilities, modern communication devices, and the elimination of unnecessary intermediate handling steps, there have been manpower reductions up to thirty-five percent in the departments conducting these operations. And what is infinitely more important, quality giveaway has been reduced and the incidents of product contamination, tank overflows and other manifestations of mal-operation have been virtually eliminated. Thus the first productivity improvement method is to reappraise the entire refining process to see that basic operating concepts have been consistently applied.

To be able to control, it is first necessary to measure. Flow, level, pressure, and temperature are variables that have been measured and automatically controlled in the processing units for many years. However, techniques for measuring many other physical characteristics and conditions are continuously being developed. An important segment of the improvement program, then, is to keep

abreast of these developments and to apply them to effect better control of existing plants. Application of a radioactive source level indicator in a twelve-year-old coking plant, for example, increased the capacity of this plant nearly ten percent. A continuous hygrometer, to cite another example, will result in large savings in another unit where trace amounts of moisture in the hydrocarbon feed promotes excessive corrosion. Other specialized primary measuring devices in various stages of application or development include continuous chromatographic analyzers, gas and liquid gravitometers, viscosimeters, colorimeters, vapor pressure instruments, conductivity devices, and many others, all opening a new gateway to improved process control.

Some units constructed in the past five years have been equipped with automatic and continuous data logging devices. These promote tremendously improved surveillance of the process, eliminating some of the human frailties.

In some industries it has been possible to define the job to be done in mathematical terms and to measure the output precisely. Thus has come about automatic production control approaching in some cases the completely automatic factory. Complete automation in the process industries has been stymied by the inability to make such a mathematical model as well as the difficulty in measuring the actual variable to be controlled. It appears that a breakthrough here is imminent. At least two process units in the country are now equipped with data logging and computing equipment which is designed to continuously optimize the units' operations, as well as to provide continuous surveillance.

The foregoing illustrates improvements possible with the installation of new physical facilities. Of even more interest are efforts to change mental attitudes. A continuous and searching review of the units' real and imaginary operating limitations is a very necessary part of the productivity improvement program. Even in plants which have seemingly operated satisfactorily for twenty years, it is possible to effect tremendous operating economies. Minute inspection of all plant capacity and economy bottlenecks is necessary. The fact that significant improvements can be made in this area does not imply that previous operation was faulty but rather illustrates that knowledge is a growing thing. This could be termed a method of successive approximations toward optimum operation. Examples of improved productivity brought about by this continual removal of cobwebs are too numerous to mention. Suffice it to say that we have hardly a unit that is not operating at a capacity or efficiency level at least twenty-five percent above design.

MECHANICAL ANALYSIS

Over twenty percent of the total refinery operating cost is in maintenance of facilities. Mechanical efficiencies, then, should receive at least a proportionate share of the energies spent in the Productivity Improvement Program.

Most important are the efforts to decrease *turnaround* frequencies of the larger units. A turnaround is the name given to the scheduled periodic shutdown of a process unit wherein various cleaning, inspection, and repair jobs are accomplished. A significant portion of the time spent is in merely shutting down and opening equipment regardless of the amount of repair work required. Upwards of a quarter of a million dollars might be spent on a single turnaround of a major unit and this does not include the loss of processing capacity during the shutdown period. By improving the accuracy of retirement predictions for individual pieces of equipment, by providing better materials where warranted, and by reducing incidents of mal-operation, turnaround frequency has been halved in several instances.

Of real importance are attempts directed towards reducing length of turnarounds and improving maintenance manpower utilization. This has been accomplished largely through the use of advance planning techniques. Several months before a turnaround, jobs are defined, materials ordered, and craft manpower is sequenced and scheduled. Punched card accounting equipment is used to facilitate this operation.

In addition to turnaround scheduling, daily routine jobs must be planned in detail to effect maximum economy. Except for emergency jobs, all work is scheduled several days in advance to permit sequencing and balancing of maintenance work forces.

The right tools must be found and used. But in addition to the proper maintenance tools as such, consideration must be given to special auxiliary services such as mobile tool rooms and safety equipment dispensaries.

Underlying all of the mechanical analysis methods is the philosophy of finding the right material for the job so as to eliminate a problem once and for all.

ORGANIZATION AND WORK METHODS ANALYSIS

Considerable attention must be paid to the basic organization structures of all of the refining departments. Largely this is a matter of being sensitive to a changing environment. For example, in two departments drastic decentralization of activities resulted in manpower saving simply because the operation had become too complex to be handled by a centralized organization no matter how large. On the other hand, other departments had decentralized to the point that only part-time jobs resulted. Our organizational ground rule here is to decentralize into unitized spheres of activity with communication permitted across the boundaries of the units rather than through a central hub.

Sensitiveness to changing environment can bring about real dividends in terms of manpower saving. Too often an elaborate training program needed when manpower turnover was seventeen percent per year, is continued

when general economic conditions have reduced turnover to less than five percent. Similarly, supervision needed in a fractious labor environment can be reduced as the economic situation changes. Manpower, which may have been needed to solve a particularly acute problem, can be reduced or utilized elsewhere once that problem has been solved. As often as not, however, a special assignment once made is apt to endure forever. Rate of improvement of productivity is an important factor. Economic climate again may dictate the need for a changed rate of improvement thus effecting manpower needs, particularly technical.

It is important, too, to look at work methods as such. Installation of a pneumatic tube to carry one-quart samples nearly one mile from a marine terminal to the laboratory resulted in a labor saving of over two thousand dollars a month. Use of a straddle truck lumber carrier to transport palletized drums of oil permitted the eventual abandonment of an entire refinery railroad system complete with two engines and a string of flat cars.

It is imperative that rigorous work or performance standards be made and adhered to. This is not easy in an operation where the output of a single person cannot be accurately measured. Some progress has been made, however, by making individuals at all levels aware that they simply are not permitted to damage or destroy themselves or their equipment, nor to waste human or material resources. This is easy to state as policy but administration of the policy requires a very thorough work-sampling procedure.

One of the most difficult productivity problems is that of recognizing and correcting surpluses or inadequacies in base staffing of operating units. Over a period of years, successive small improvements in control equipment, handling methods, process understanding, etc., may lead to a subtle staffing surplus condition. Each of the improvements in itself may not have significantly affected the work load. Yet, taken as a whole, it is frequently found that a twenty-five percent overstaffing exists in a plant that was pretty well balanced when it was first started, perhaps ten or fifteen years ago. These problems must be faced and corrected, preferably by taking additional work-load reduction steps and then making a total work-load/manpower balance.

OPERATIONS ANALYSIS AND PLANNING

In the area of operations analysis and planning are the most subtle, but undoubtedly the most significant, methods and tools to effect gross productivity improvement. Consider first operations planning. The petroleum industry from field to consumer is indescribably complex and at every point of transfer and at every stage of processing great uncertainties exist. From the crude lot purchase subject to a last minute price negotiation, to the half-million-barrel tanker delayed by weather, to the processing unit beset with a mechanical breakdown, to the customer who might, or might not, place a large order, these operating uncertainties can snowball into a state of complete chaos. To stabilize the system and yet retain the flexibility to take advantage of spot purchase and sales opportunities, a very comprehensive and somewhat unique planning system was devised for the entire company. Recognizing that uncertainties do exist, each operating segment now forecasts its operation three months in advance on a minimum/maximum basis. Consequently other segments affected at the transfer points can make contingent or alternate plans. For example, the marketing department predicts that there will be taken from the refinery at least a minimum amount of a product, but that within certain confidence limits there may be a demand for a much larger amount. Thus the refinery is assured of having storage room for a minimum production quantity and makes alternate plans for shipments up to the maximum possible demand. Wherever possible, automatic decision rules have been formulated for each planning step. It is apparent that this kind of problem is ideally suited to mechanical data processing techniques. A part of the system has been so converted but much remains to be done to completely mechanize this most complicated problem of refinery production scheduling.

Closely allied to improved production scheduling is the mathematical analyses of operating units to determine their optimum operating conditions as a function of feed and product characteristics. Even though it may be desired to stop short of applying this directly for automatic unit controls, these operating models will be extremely valuable both in actual operations and in simulation of operations. A certain amount of analysis of this type has always been done but the availability of high speed computers makes more rigorous solutions possible.

Studies have been undertaken to define refinery tankage requirements in terms of throughputs, uncertainties, and lot sizes. These studies have been used to justify new tankage in some instances and reassignment of service in others. Tankage represents a considerable capital investment, and efforts leading to more efficient assignment yield a high rate of return.

Linear programming techniques to optimize refinery blending stock usage are becoming increasingly important. It is possible to determine what any non-optimum operation can cost and adjust refining or marketing controls accordingly.

Finally, in the area of operations analysis, it is necessary to study the profitability of individual items of production. For example, it was determined that seventy-five percent of the products accounted for only ten percent of the volume of sales. When this seventy-five percent was discontinued, manufacturing and marketing efforts were concentrated on the more profitable balance. The net result of these profitability studies has been a simplification of the product line resulting in large re-

finery operating economies. A side benefit accruing from these studies is the awareness at all operating levels of what refinery net-backs or product price realizations mean and what undesirable diversions or uses of refinery stocks can cost.

SUMMARY

The point has been made and illustrated that productivity must be defined in terms of the entire manufacturing objective. To think in restricted terms of "cost reduction" and forget "profit improvement" or to stress "manpower elimination" rather than "manpower utilization" can be disastrous. In addition, the definition must be applied to the integrated activities of the entire company. It is entirely possible for the productivity of an individual segment to be below optimum in order that the productivity of the whole may remain at maximum.

Further, it has been suggested that in order to be assured that all areas of potential improvement are covered, the Productivity Improvement Program should be formally outlined and available resources and talent carefully allocated to the various segments.

It can be argued that these points are axiomatic, that it is hardly necessary to talk about things so fundamental to management and administration. And yet the fact of life is that these things are not self evident especially at the operating levels where the degree of profitability is largely determined. Too often productivity is considered only in terms of more production, or better production, or more services, or better services, or in terms of more automation, or more computerizing. And thus the profit motive is lost.

Productivity in Food Processing

by **A. L. BUFFINGTON**

Production Manager, Diamond Walnut Growers, Inc.

DIAMOND WALNUT GROWERS has been in operation since 1912. Its major function was, and still is, the marketing of the state's walnut crop. Originally the walnuts were marketed in 100-pound bags in-shell. The processing function was an afterthought forced upon the company by economic developments in the marketing of food products. As demand for prepared foods and unit packages increased, the company was forced to develop its processing facilities. At present it is a typical food processing industry. We receive walnuts from growers at local packing houses which act as collecting points and do preliminary culling and processing. The walnuts are then moved to a central processing plant at Stockton, where they are branded and packaged in-shell, or they are shelled and packaged to be sold as walnut meats. Processing industries typically are characterized by large volumes of raw material, a substantial capital investment, a small complement of employees, and a relatively fixed production flow from one step to the next. Physically we differ only in that traditionally the number of our employees has been high in relation to other processing industries. Organizationally, however, Diamond Walnut Growers has lagged as a result of the secondary role which the production operation played in the early years of the company. The result of this lag in organization was the development of a production operation of surprising magnitude but rather elementary organization. No staff operations existed as such, and Cost Accounting made no attempt at the development of detail production costs. Previous efforts by Production Supervision to create an Industrial Engineering function had failed, due to the lack of support of top management and general skepticism among older employees. The general attitude which resulted from this situation was, "We tried it and it didn't work."

CHANGES

In 1955 the decision was made to move the company's main plant to Stockton, California, in order to keep the main processing plant close to its source of supply. This decision, which had far-reaching political implications within the company, resulted in a thorough shake-up of company management. As a result of this shake-up, a new management group gained control of the company and was immediately confronted with the following production problems:

1. Completion and start-up of the new plant.
2. Improving the existing processes.
3. Continuing processing operations in the existing plant.
4. The development of staff activity in a well-rounded manufacturing operation.

As I have mentioned previously, the Production Staff of Diamond Walnut Growers was not familiar with the concept of staff operation and had never worked with Industrial Engineering as such. Accordingly, we decided not to attempt to introduce an Industrial Engineering staff as such, during a period of considerable unrest. Although this need was clearly recognized, we felt that we could introduce the concepts and procedures of Industrial Engineering as a means of improving the existing processes and increasing production, and at the same time create an atmosphere in which an Industrial Engineering Department could successfully take hold at a later date.

INDUSTRIAL ENGINEERING TOOLS

In developing the processes for our new plant and laying out machinery, we began with four of the fundamental tools of Industrial Engineering, namely: process analysis, flow charts, layout diagrams, and Gantt charts of completion covering all installation steps. The activities of our production group fall into three natural divisions, namely: Shelling, In-Shell Cellophane Packaging, and Warehousing. Of the three, Warehousing was the most efficient in its operation and represented the smallest item

of expense. For this reason, we dicided to concentrate our efforts on the Shelling and Cellophane Packaging Operations. Early investigation had shown that each of these two operations was badly in need of overhauling and held promise of considerable savings in labor. Accordingly, we assigned a group from each of these two departments to the problem of perfecting methods and developing a recommended layout. In handling this problem, the groups were taught to use Industrial Engineering techniques of investigation, and every effort was made to question each step of the operation. I might add that at this point the old technique of work simplification proved extremely effective, and the results, as demonstarted by our first year of operations in the new plant, were more than gratifying. After the initial processes and layouts had been developed, the information gathered from process analyses and flow charts was again used in the training of operators. Process analyses also proved extremely valuable in identifying and eliminating bottlenecks in the initial phases of operation. An analysis of our first year of operation showed that we had been able to reduce our peak crew from approximately 2,775 people to 650 people. This reduction had occurred as a result of three major types of improvement.

1. A substitution of machines for hand operations as typified by the installation of automatic packaging machines and electric eyes for color sorting.
2. A very thorough conveyorization coupled with an improved layout which sharply reduced the time and labor occupied by material handling.
3. Elimination of unnecessary steps.

I believe that this approach has been the most effective method of utilizing Industrial Engineering during our initial phase and at the same time was securing its unconscious acceptance by our line personnel. It has also provided us with the answer to a rather pressing problem during the startup phase, since we needed a larger number of Industrial Engineering personnel than would have been possible to obtain or to insert into the organization in such a short time.

We are now in the midst of our second year of operation. It is interesting to note that continued use of the questioning techniques of Industrial Engineering by supervisory line personnnel has resulted in almost as many improvement projects as we put into effect during the construction of the new plant. We have attempted to encourage the use of this approach by assigning methods improvements projects to line supervisors and continuing to encourage them in the use of Industrial Engineering techniques. This program of methods improvement and cost reduction by line personnel, using Industrial Engineering techniques, was the first step in our plan to sell Industrial Engineering.

TAKING STOCK

After the initial problems of startup, the second step of our development could logically be placed under the heading of Taking Stock. This particular phase hinged largely upon the development of a thorough cost-accounting system and later upon the installation of industrial cost control. Our approach to this problem began with a series of meetings between the Production Department and the Accounting Department, in which we first, divided the various production departments into cost centers where responsibility could readily be defined and where costs could be isolated; and second, designed a new chart of accounts which made provision for the cost breakdowns which we felt were necessary. Finally we initiated the collection of controllable costs by cost centers and began regular reports covering controllable costs. At this point we knew what our costs were.

The next, or third phase, is developing the answer to the question—What should our costs be? At this point the application of Industrial Engineering techniques by line personnel becomes inadequate, and the development of a staff department becomes necessary. I believe that we are now ready, since the proper climate for the successful development of an Industrial Engineering Department has been created. By now, all key line personnel are familiar with the job to be done by an Industrial Engineering Department and have become convinced that the techniques which will be used by this department are effective, for the simple reason that they have used these techniques themselves and have seen them accomplish tangible results.

COST STANDARDS

We plan to train a small group of job study engineers and to immediately develop the initial cost standards by which to measure the cost data which we are presently getting. This evaluation of present performance with the resulting follow-up on areas of weakness, will provide us with adequate material for our last major step in Industrial Engineering application, namely: the active participation of staff members of the Industrial Engineering Department together with line supervision in a very thorough program of methods improvements so that each operation is performed in the one best way.

With the completion of these steps, we will have an Industrial Engineering Department which will be performing the major functions for which it was designed. These are,

1. The work with line personnel in improving methods and reducing costs.
2. The establishment and maintenance of cost standards.
3. The assistance in the planning and follow-up on cost of major construction projects.

EDP—Promise for Greater Productivity

by **WESLEY S. BAGBY**

Comptroller, Pacific Mutual Life Insurance Company

ONE of the greatest opportunities open to Industrial Engineers today is in the field of improving clerical methods. It is a virtually untapped field, and is becoming increasingly important. Fifteen years ago in this country there were only 5 million clerical workers. Now there are more than 8 million. As industry has become more complex, it has required an increasing proportion of indirect to direct labor. There has been almost a fifty percent increase in the proportion of clerical to production workers in the past fifteen years. Projecting this trend into the future, 1973 will find clerical workers harder to get than scientists are today. This will be true unless there are major changes in the nature of office work.

CLERICAL MECHANIZATION

I believe that you experts, through the intelligent use of clerical mechanization—particularly electronic data processing machines, will reverse this trend. You have already worked wonders in factory methods. The time is now ripe for you to make similar improvements in office and clerical methods. EDP is the new tool at your disposal—a tool that under your skillful guidance can be used to take over many of the monotonous, repetitious tasks now done by clerical workers.

Some of you may be thinking "Well, that's all right for large companies, but I can't use it—my operation just is not big enough." I'd like to call your attention to the fact that less than 10 years ago a prediction was made by supposedly qualified authorities that "fewer than a dozen electronic computers will be able to satisfy the entire requirements of the United States."

Whether or not the use of a computer would have improved the accuracy of this forcast will never be known. What is known is that as of last February, 241 large and 1,036 medium-scale machines were already installed. When these are added to the 4,750 small-scale machines in the field, you find an impressive total of more than 6,000 digital computers already in use or being readied for actual use. And this by no means satisfies industry's requirements, for right now about 3,300 additional computers are on order from U. S. manufacturers—280 large-scale, 1,320 medium, and 1,700 small-scale. And everyone of these is a tool which can help you do a more effective job.

AN ACTUAL EXPERIENCE

We at Pacific Mutual Life Insurance Company are not experts on the subjects of Industrial Engineering and electronic data processing systems. However, as one of this growing group of companies who have "gone electronic," I believe our experiences may be of interest to you. The studies made before selecting an appropriate system, the special problems of conversion, the benefits already evident, and the basis which our EDP system lays for further improvements in clerical productivity should be fairly typical. These same factors have been present in greater or lesser degree in every installation with which I am familiar.

A few facts about Pacific Mutual will help put experiences into proper perspective. We are a medium-sized life insurance company which also issues accident and health and group insurance. We operate nationally from about 150 offices. We have over 2½ billions of life insurance in force, half of which is in about 350,000 individual policies in our ordinary department. We will pay out over $85 million in benefits to our policyowners and their beneficiaries this year. The total office force in our Home Office here in Los Angeles is about 900 people. In September 1956 we purchased a Univac Model I electronic data processing system, primarily to do all the billing, accounting, and record keeping on our 350,000 individual policies. We have had it fully in use on this basis since last November.

PREPARATION FOR CHANGE

Now, for a few comments on what we did before we decided on this course, and why. We first became interested late in 1952. A few months of intensive study convinced us that the general purpose electronic data processing systems then available or being planned were designed with our paper-work problems in mind. It appeared that they could efficiently do most of the work of recording, calculating, verifying, posting, and record-keeping that we were performing with some 400 of our staff and an extensive tabulating department. Of course, the manufacturers of large-scale equipment were eager to prove to us that their particular systems could save us money (and several of them were convinced of this), but it seemed to us that only our own people could determine this on an unbiased basis.

So management, late in 1953, appointed a five-man committee to determine whether the Company should acquire an electronic system, and if so, what type. The five members were responsible for the systems in the areas where the electronic system would probably apply, if acquired, and they were high enough in the management picture to assure executive reliance on their judgment.

Because of our relatively small size, it was easy for the Committee to decide that we could not possibly justify even a medium-sized system for a single operation, such as premium billing and accounting. When they explored the possibility of consolidating functions (rethinking our entire operations on our handling of individual insurance policies) it appeared that an electronic system might be productive.

ESTIMATING THE FACTS

This required putting together all the facts about our present methods in order to have a factual basis for comparing costs. Our ordinary insurance operations (premium billing and accounting, commission calculation and payment, reserve and dividend calculation, loan and other policy payments, and file maintenance) were carried on in seven departments which reported to five different executives. It was decided to study in detail the volume of all tasks performed in every job in each one of these departments. To this end a detailed time study was kept day by day, by every employee who might be affected directly or indirectly for a full month.

This gave us an estimated record of activity that occurred daily, or on a weekly or monthly cycle. The committee recapped these individual time records into a divisional time inventory. Each of the seven department heads was given a copy of his divisional time inventory for review and action in connection with these current routines. In many instances, as was expected, the time study pointed the way to real improvements that could be made in present systems without resorting to electronic methods.

The committee used these divisional time inventories for charting present routines of the individual insurance activity processing area. To these flow charts in turn were matched the man hours developed in the divisional time inventories, adjusted downward in those many cases where the time study had shown that the present system could be improved, even without adoption of electronic methods. Analysis of the man-hours in the seven departments showed that 57% of the hours expended could definitely be handled by electronic methods, 37% could not, and 6% were in a doubtful area which might or might not be able to be included in an electronic processing system.

Factors based on our known costs for clerical operations were applied to the percentages of total man-hours thus determined. We used a standard based on *routine* clerical man-hours, recognizing that computer operations would replace and release man-hours far less costly than our average over-all man-hour costs. The hourly cost assigned included overhead in the form of fringe benefits, but did not include such items as space occupied nor equipment used by the individuals.

I should mention that our definition of work to be performed by the computer was based on studies made with the assistance of IBM and Remington-Rand. These two independent studies when compared showed that while the methods differed the over-all area of work embraced was about the same under either method. This gave us a fairly well defined area of operations to be performed by a computer even though at this stage we had no knowledge as to whether or not *any* computer would be found to be desirable for our operations. It followed then that a special computer might be desired.

DECISION

In April 1954, after almost 10,000 man-hours of study, the committee presented management with a comparison of costs which showed that investment of $2,000,000 for a large-scale system should pay its way fully in five or six years on our individual insurance application alone. The savings resulted mostly from reduced clerical costs and some slight reduction in cost of renting punch-card equipment. In the cost comparison, we included loss of interest we would receive if the money were otherwise invested. We gave no weight to the greater amount of current information we would have under the proposed new methods, even though we were sure it would enable us both to improve service to our policy owners and field salesmen and to make better management policy decisions.

Two months later management decided to go electronic. The committee was instructed to study available equipment, and equipment that was "just around the corner," to determine what would be best for us. At this point we did several other things. We started to prepare additional personnel for the coding and programming work we knew was ahead, planning for a programming staff of thirty in all. Our methods department started to work on the space problem. We needed 7,000 additional square feet to house our installation, our programming group, and the thirty other people we expected would be needed for data conversion work. We analyzed every proposed change in our conventional methods to be sure that the change, if made, was thoroughly compatible with our proposed electronic system.

PURCHASE & INSTALLATION

In September, 1954, the committee recommended the purchase of a Univac Model I system. Not only did this appear to us to have technological advantages, but it was the only thoroughly field-tested equipment that could be purchased as opposed to leasing. We knew it was technically obsolete, but did not consider this important as long as it could economically perform the job for which we'd gotten it. There is a vast difference between technical and economic obsolescence. In addition, we protected ourselves contractually by providing for later exchange for a newer model, at our option.

The system was delivered in August, 1955, and was fully operational two months later. On our consolidated functions approach, programming is very complex. There were more than 75 man-years needed to complete the long series of programs which told Univac exactly how to do our individual insurance work. In September, 1956, after almost a year of program testing, we accepted the equipment. The next 14 months were devoted to conversion of our data to the new system and parallel operations.

CONVERSION PROBLEMS

I'm going to spend a little time on the plans for and

special problems of conversion. It is an important area, and one in which almost every electronics user has underestimated the costs and the time required. Your special talents can pay you and your organization well if they are concentrated on details of conversion plans and operations in the very likely event that you find yourself working with new electronic applications in the future.

We had planned to convert our work in eight segments, each with from 10 to 15% of our total volume. Late in 1956 we were running completely parallel operations—old and electronic—on the first 15% segment. This was continued over the year-end and for the first two months of 1957. In March of last year we eliminated our old systems on this part of our business. During this same period, of course, we were electronizing additional segments of our business.

Initially, we had not thought it would be necessary to run any parallel operations after the first segment of our work had proved the accuracy of our programming. In practice, however, we found that so many errors and discrepancies had been built up over the years in our old manual and punch-card system that it was essential to reconcile all of these before we became dependent on the tape operation. As each of the seven remaining segments of our business was converted to tape-handling, several phases were checked out carefully without running extensive parallel operations. The last segment was converted and we were operating fully electronically starting last November.

This conversion work was more costly and required more time than we had originally planned. During the period of parallel operations, which ran for about 3½ months, any change concerning a particular policy had to be recorded in duplicate—on the tape used in our new system, and on the individual punch cards and visual records which were part of the old system. In many instances from 10 to 14 individual card records were needed on one policy under old methods, all replaced by one record on about an inch and a half of tape on our new system.

PERSONNEL PROBLEMS

We had realized that during parallel operations an extra group of people would be needed. We used our most highly skilled and experienced people on the new tape methods. We used our regular group of clerical workers on the old methods, although their effectiveness was lessened because we had pulled away the most competent from their group. Originally we had expected to use the staff assigned to the new methods to compare their results with those obtained under the old conventional methods. In practice this was just too much, and we found that we must have a third group of people to compare the results under the two systems. This third group had to be the most highly skilled of all, because they had to be thoroughly familiar with both new and old systems in order to check out final results.

Unfortunately, our need for more clerical workers came at a time when the labor market was extremely tight. In spite of an aggressive hiring campaign, we just weren't getting enough of the right kind of people to handle the conversion workload. One week-end we had a three-day brainstorming session on our entire electronic program. One unique idea coming out of this was "Project Helpmate." We offered six months' temporary employment to wives of our employees and officers. There were only two requirements—they had to have had some clerical experience, and they had to agree to stay six months.

Project Helpmate was an amazing success. Over seventy wives came in, enthusiastically. All but two stayed the full time. Most of these wives had worked in periods when work habits were better than those of today's high school graduate. They also had an intense desire to get the job done. Our younger clerks rose to the challenge—they weren't going to let those old "biddies" show them up. Output, as well as morale, improved tremendously. Had it not been for these wonderful wives, I believe our conversion might easily have taken six months longer to complete. Incidentally, our experience in underestimating the number of people and time required to complete conversion is reasonably typical of that of other EDP users.

CONVERSION COMPLETED

For almost eight months now, since last November, our individual insurance work has been entirely dependent on our new tape methods. We've discarded the millions of cards we used to have, and have all the data about our 350,000 policies on some 60 reels of tape. We are on a daily cycle basis, which means we process our entire master file of 350,000 policies each night. There is activity of one sort or another on about 2% of these policies every day.

We're running our Electronic Records Department three shifts a day, five days a week, and an extra shift or two on weekends. It is an all-tape operation. Records of premiums paid and policy information requested are typed on tape. These tape records are matched with the master file during the night's run, and early the next morning we have a completely new updated master file. We also have collateral tapes which include details of all the policies on which changes have occurred or information has been requested.

During the next shift, these various collateral tapes are processed. Early the next morning we have print-outs of complete status for all policies on which information was requested the day before. These are in the correspondents' hands for answer that day—within one working day of the receipt of the request. By early afternoon of the next day after our master run, we have complete records of the accounting and distribution of all premiums paid, commission calculations thereon, policy-loan, dividend, and other actuarial calculations due to be made and pre-

mium or policy loan interest bills which need to be mailed. We also have the inevitable and highly important accounting and statistical summaries of everything that has happened to our entire group of individual insurance policies.

RESULTS

What about productivity? Do we find that we have accomplished as much as we expected to when we embarked on our EDP adventure? The answer is definitely "yes." I'd like to tell you of five separate areas in which our EDP system is leading to greater productivity.

The first of these is in reduced clerical costs. Perhaps this is the most important of all because it is the one that everyone can see and understand, and the one which we, in common with most other EDP users, felt was essential to justify an installation in the first place.

To show how our clerical costs are reduced, we have about 75 fewer people working on the accounting and servicing of our individual policies than we had originally. We also have eliminated over a third of our tabulating equipment. This is true in spite of the fact that there is now an appreciably larger volume than there was before we went electronic, and the further fact that our Electronics Department alone has a staff of 60 people. Net, we can safely say that we have about 100 fewer people in this area of work than if we had continued on our old basis. As the new organization shakes down, and as the retraining of our relocated older workers continues, we expect we'll be shaving off another 50 job stations within the next year. This reduction in personnel was accomplished through normal attrition—no employee was released due to our electronic program.

There is one other small operation which has been on our Univac for more than a year. This is billing and service work for certain group policies. This is a simple job which takes only two hours a week of machine time, and which required only three man-years of programming. It has saved us twelve clerks in our Group Department. We also had an unexpected savings on this job in the way of a $700,000 reduction in the amount of our due and unpaid premiums because our billing work can be kept fully up to date electronically. On this amount we're able to earn our additional $25,000 each year.

A second area of improved productivity is in space. We have been able to release 10,000 square feet from replaced job stations. You'll notice that this only a net savings of 3,000 because our electronics department took 7,000. Our prior operations were badly crowded—our new departments are being planned on a basis that provides proper space for five years' growth. For the first time in a generation we have space available in which to shuffle departments and divisions around. We're taking advantage of this to vacate an area at a time and modernize with new floors, new lights, dropped ceilings, and modern decor.

This modernization program will embrace four floors in all, essentially all of the operating departments engaged in individual insurance activities as well as most of the Company's technical and service departments. As an area is completed and its permanent tenant is moved in, it will be into a completely rearranged set-up, with departments located on a functional basis. We know this will lead to increased productivity and reduced operating costs.

A third area in which our EDP is already bringing marked improvements is in service to our policyowners and our salesmen. All pertinent information about the status of a policy can be printed out simultaneously after a single interrogation of the master-file tape. Under old methods, records of six or seven departments had to be searched and collated before full data were available. This allows us to give prompter and more complete answers to inquiries from policyowners. It is also possible for us to give our salesmen in the field more up-to-date information about the status of their clients' policies, and prompt notification if a premium is not paid when due so that a service call may be made.

A fourth kind of improvement possible because of electronic handling of our individual policy records is in better merchandise. With the speed and flexibility of an electronic system, it is possible to offer, in one package, a variety of coverages which would be too costly to administer under mechanical or manual methods. For example, you can now purchase permanent life insurance, add a term rider, include premium waiver, double indemnity, monthly indemnity payments in event of accident or sickness, hospital benefits, and even similar coverages on your wife and children under a single "package" policy and in an almost infinite variety of combinations. Univac will keep all the records and distribute the one premium you pay among these various coverages. Univac will also handle the commission allocation and statistical records. We were unable to tailor-make a policy to an individual's needs to anything like this extent before electronics. The multiplicity of records which would be required every time a premium was billed or paid made the costs prohibitive.

Better information is a fifth way in which EDP is leading us to greater productivity. As a by-product of our daily run, we have an instantaneous summary record by number and amount of all types of transactions which affect individual policies. These data are available daily, and can automatically be accumulated weekly or monthly when appropriate. If we need a list of all our policyowners who now live in Arizona, or Louisville, regardless of where they may have purchased the policy or of where they pay the premium, it's available for the asking. We are able to provide each agent with a list (or series of cards) of all his policyowners, in order, by their birthdays. Information of this type is useful for sales promotional activities. Even more important is the ready availability of current, complete information on *all* our policies. When we learn to use this, management policy

decisions are bound to be better. They'll be based more on facts and less on impressions.

THE FUTURE

What about the future? We are planning to replace our Univac I with a Univac Model II later this year. That will give us added machine time for new applications such as mortgage loan accounting, group insurance statistical work, general accounting, and some others. We believe that we will have our entire investment back in a little less than the five or six years we originally expected. This is on the basis of savings in salaries and tabulating equipment only, and gives no weight to space, better service, better merchandise, nor better information.

What does this all mean to you? You, who are concerned with improving productivity, have a very valuable new tool to help you. Electronic data processing is here to stay. Investigate, see how it can help you become more valuable to your organization. As you explore this fascinating field, you'll find more and more ways in which you can put it to work. As you do, there will be interesting experiences ahead—experiences that will frustrate you occasionally, enthuse you often, and challenge you always.

Reducing the Costs of Ocean Transportation

by **JOHN M. GILBRETH**

Manager of Operations Research, Grace Line, Inc.

FROM the viewpoint of cargo handling, the maritime industry had made, until recently, little progress. The method for stowing and discharging cargo is, for the most part, basically the same as in the days of sailing ships.

Materials handling equipment including such aids as fork trucks and pallets has been brought to the waterfront. This undoubtedly has made the longshoremen's job easier. However, no appreciable gain in productivity has become apparent and in many cases productivity per man hour has actually decreased.

Along with all other industries, the steamship companies have paid out wage increases, but without a corresponding increase in productivity. Because we are approaching the breaking point in passing on increased costs to the shipper, a squeeze has resulted between selling price (the freight rates) and costs.

POSSIBLE ALTERNATIVES

For the carrier of general cargo, there are at least three possible plans of attack on the price-cost squeeze. One alternative—which is beyond the scope of this presentation—is to withdraw from the industry and sell your fleet. A second is to increase freight rates. Raising prices in any industry meets with varied amounts of resistance. In foreign commerce today, adequate increases in freight rates could result either in reduced demand by the ultimate consignee or in diversion of his purchases to foreign manufacturers using foreign flag ships. The effect would be to price the U. S. flag carrier out of the market.

The third alternative and the one that is receiving the most attention at the present, is a concentrated attack on costs. This attack covers the gamut—starting with detailed analyses of present costs and methods to complete fleet replacement using specially designed ships.

In analyzing costs, Grace Line and certain other common carriers of general cargo have found that cargo handling represents at least 50% of their total voyage expense. A substantial portion of the balance is uncontrollable, including such costs as fuel, oil, port charges and, in part of our service, Canal tolls. But the cargo handling portion, which includes receiving, stowing, loading, discharging and making delivery—represents the costs which can and must be reduced if the common carrier is to survive.

REDUCING CARGO HANDLING COSTS WITH PRESENT SHIPS AND EQUIPMENT

In order to discover ways of increasing cargo handling productivity, detailed time and cost studies of all elements of stevedoring have been and are being made with special emphasis on the cause of delays. The reports published on this subject by the Maritime Cargo Transportation Conference and by the University of California at Los Angeles have received careful study by the industry. Their findings indicate, among other things, the desirability of reassigning members of the stevedoring gang according to the commodity being handled. They also show the wide variations of productivity per man hour in various U. S. ports. From the operator's viewpoint, these studies confirm the belief that size of the gangs is unnecessarily large and productivity unnecessarily low.

A desirable by-product of cargo handling cost information is that the operator can then determine profitability of type of cargo. This can be carried beyond the profit per revenue ton to the profit per *cubic foot occupied* when stowed in the ship. For operators whose ships are normally "full" before they are "down," the space-occupied basis is significantly more important and their freight sales division can be guided accordingly.

In another attempt to increase productivity there has been increased utilization in the trade of pallets, knockdown pallets and shipping containers. Pallet exchanges have evolved and various methods of tie-down and gluing unit loads are being used. Certain operators in the U. S. and abroad have realized substantial savings from stowing cargo on pallets. Others have stated that, while ship dispatch has improved, their cargo handling expenses have not changed due to costs of strapping or tie-down and to pallet loss and maintenance. Still others have rejected pallets because of wasted space in the ship. As is to be expected, the method which is right for one operator does not necessarily apply to another.

A matter of increasing interest to the steamship operator and to shippers in general is the use of shipping containers. By the use of the common 275 cubic foot container the operator can about triple his stowage rate of highly pilferable cargo. However, operators are becoming increasingly aware of some of the disadvantages of using containers on *conventional* ships. These include such cost items as: depreciation and maintenance of the containers, labor to fill the containers and space sacrificed in the ship to the cube occupied by the container. As an example, a study made by Grace Line has demonstrated that on our conventional C-2 dry cargo ships this lost space would theoretically rule out all container shipments except those that are door to door two-way movements.

There is, however, a continuing trend toward domestic packing of export shipments which can only lead to more damage and pilferage unless carriers provide containers for protection of the cargo.

REDUCING COSTS THROUGH NEW SHIP DESIGNS

A number of American steamship companies have contracted to replace their fleets with new vessels within the next ten to twelve years. With the advent of specially designed ships for wine, orange juice, lumber and other commodities, operators are naturally taking a long look at cargo handling methods and ship design. The carriers of general cargo are particularly interested in the container ship concept, especially the roll-on, roll-off and lift-on, lift-off methods.

In determining the overall economics of container ships, many factors are being analyzed and evaluated, such as: the point of origin of the cargo, its density and volume of movement, the length of the voyage, the amount of two-way movement, labor restrictions, etc. Other factors are more difficult to evaluate such as: the proportion of the containers filled at the shippers' plants; the effectiveness of the resistance to change; the speed of standardization and interchange between the various modes of transportation. Because of these uncertainties, we can first expect conversions of existing ships before we see whole-hog fleet replacements with new container ships.

To the carrier of general cargo, the container ship offers the possibility of a large unit load carried, door to door, untouched by human hands. To the shipper and to the consignee it could mean lower costs and better outturn. On the East and Gulf Coasts, the Pan Atlantic Steamship Corporation has already proved the concept is practical and economical in coastwise trade.

It does not follow that a container ship is or will be "right" for all trade routes. We must, however, examine its possibilities from all angles, because the container ship and integrated movement could be an answer to ever-increasing cargo handling costs.

Productivity in a Retail Store

by **ALVIN M. FERST, JR.**

Superintendent, Planning and Plant Management, Rich's, Inc., Atlanta

GENERALLY speaking, the retail industry has lagged behind other industries in applying sound engineering practices to the running of their business.

Personally, I have always felt that the same sound practices that are used in the manufacturing industry can be applied in modified versions to the retail industry. Fortunately, for Rich's, this idea is shared and has been taught and practiced for the last thirty-five years at our store by Mr. Frank Neely, Chairman of our Board of Directors. Mr. Neely was one of the early Industrial Engineers working with Mr. Gantt, Mr. Taylor and Mr. Gilbreth long before "Cheaper by the Dozen."

For many years "Productivity in Retailing" meant—"get more sales." A sales increase was the "cure-all" for expense control. The merchant was trained to understand expenses only as expressed as a percentage to sales, just like he understood dollar sales per square foot of floor area as a measure of the productivity of the floor space he used. But he was not trained in the *how* of setting proper standards, or how to get more productivity to benefit the employee while at the same time properly controling his expenses.

INCENTIVE SYSTEM

Our first real incentive system was installed about thirty years ago. The salesclerk, in those days, represented the largest percentage of the payroll and was then, as she is today, the key person who represents the store in meeting the customer. Therefore, our first standards were set in this area, and our "quota-bonus" system is basically the same today. It has since been used by most of the large retailers around the country. The success of the "quota-bonus" system lead to the later establishment of work measurement standards in most of our sales supporting departments, and wage incentive systems in our small package delivery department, checking and marking rooms, furniture delivery department and home furnishing workrooms.

I will briefly attempt to review the merchandise planning and the "quota-bonus" systems as representative of what has been acomplished in sales areas and expense planning and delivery study in the non-selling areas.

QUOTA-BONUS SYSTEM

The "quota-bonus" system is just what the name implies. The salesperson is assigned a sales quota based on her base salary and the basic sale commission in the department. Sales help is planned on the basis of 25% of sales being made over quota with the salesperson earning bonus commission for all sales over quota. This system

basically:

1. Establishes an equitable commission for each classification of merchandise or department in the store.
2. Provides a monthly quota of sales for each salesperson.
3. Pays a commission—usually one-half of base commission—on all sales over quota.
4. Pays the salesperson his base salary even though he does not sell his quota.
5. Enables managers to budget the sales force in relation to sales plans and to encourage each salesclerk to earn a bonus.
6. Increases base pay at periodic reviews on the basis of productivity, thereby increasing earnings.
7. Pays bonus on monthly sales over quota with no carryover on months that quota is not realized.
8. Charts weekly production as percent to quota in relation to other salesclerks.
9. Encourages monthly review by the service manager and buyer with each salesclerk to show sales, returns, attendance, selling cost and bonus earnings.
10. Provides weekly production and daily production figures for the supervisor to judge total department production.
11. Establishes a sound budgeting mechanism that allows intelligent planning of manpower requirements in line with volume, as far in advance as sales plans are known.

This system has been invaluable in insuring impartial evaluation of salesclerks and encouraging self-development, in addition to providing an equitable compensation plan.

The planning of salespeople encompasses the base force as indicated by the "quota-bonus" (planning, the evaluation of transactions to be handled, the demands for floor coverage due to the physical layout, the use of contingents or part-time sales clerks to handle peak loads) along with "good old Yankee ingenuity" in moving people from department to department to take care of the "peaks" and "valleys" that are so prevalent in our business.

SMALL PACKAGE DELIVERY

Atlanta's continual outward expansion in all directions made it necessary, in 1954, to completely replan the delivery routes that had been established in 1947. We decided at this time to also study the entire delivery operation in an effort to modernize the methods and procedures and then to establish an incentive pay system for the drivers. I might mention that before the study, the drivers were delivering packages until 10:00 or 11:00 at night. In addition to this being an annoyance to customers, the late deliveries were causing an abnormal amount of overtime, which, of course, resulted in an increased delivery cost. Now that the incentive system has been installed, overtime has been reduced, driver income has increased 28½ percent, and packages delivered per hour per driver have increased 17¾ percent.

We live by a policy that many stores only give "lip service." At Rich's "the customer is always right" and we have been known for 91 years to give service far above all near competition. Therefore, it made it much tougher to set the standards for the drivers, who are the last link in completing a transaction and whose impression on the customer must be one of service and satisfaction. After taking about 5,000 time study readings on each of the cyclic elements on the 41 routes, it was determined that the standard for "talking to the customer" was .15 minutes. We arbitrarily changed this to .25 minutes to insure that time was allotted to courteously take care of the customer. One of the key basic changes that resulted from the detail method analysis was the development of a unit system rather than a rigid route system. The unit system enables us to easily combine as many as 10 units into a continuous route in off-peak times in place of, say, 4 units around Christmas time. Other significant results of the method study were the development of a card file system by streets and street numbers to indicate exact standard routes, the posting of route maps on the delivery route bins; the routing of packages onto shelves that can be lifted from Unistrut racks into the trucks; and the introduction of night loading operations at peak times.

Prior to sorting of the packages onto the route shelves, the method studies showed packages were being handled as many as 8 times by the driver in the sorting operation. The night loading operation provided the drivers from 1½ to 4 additional daylight hours to deliver packages to the customer.

Until this system was installed in 1954, the manager of the Small Package Delivery Department had no way of measuring a driver's performance—no means of telling whether a driver was doing an outstanding job or was soldiering on the job.

After the performance standards were set, we decided that a simple method had to be devised to objectively explain the daily standard to the driver. A chart was developed showing for each route the check-out time in the morning, drive time to the route, and drive time from the route. A second chart shows additional standard time allotted for any given number of C. O. D.'s from 1 to 100. A third chart shows additional standard time allotted any given number of "pick-ups" to be made from 1 to 100. A fourth set of charts shows standard time allotted on regular packages for combination of the element, "walk to house," "talk to the customer," "walk to truck," "sort packages," and "drive to next stop" for each of 41 routes for package loads varying in multiples of 5 packages from 20 packages to 500 packages.

The next step in going into an incentive program was quite simple. We decided to adopt the "standard hour" system which meant that if the driver left with an 8.18 standard hour load and returned in 6 hours, he would obtain a 2.18 hour bonus, which would be paid at his regular hourly rate.

UNIT CONTROL

Stock planning and purchasing through unit control at Rich's is a basic tenet that one must not only know

but also be completely sold on. In this perpetual inventory system departments are dissected into classifications of merchandise. A basic stock plan is developed of "never out" merchandise for each of these classifications. In addition, seasonal goods, new fashion goods, prestige merchandise, and promotional merchandise is added to the units of basic stock which results in a total dollar stock plan that is developed by weeks, six months in advance. This must be planned in relation to the planned sales to give the proper inventory turnover. Once this stock plan is approved, it becomes a buying plan. Each item of merchandise is accounted for by classification and by unit from the time of purchase through the point of sale. This procedure of planning stock by units and recording inventory of sales by units provides a perpetual inventory and a means of analyzing current sales and stocks to take advantage of customer trends in buying when sales are exceeding expectations, and to "mark down" slow moving goods when less advantageous purchases are made. In essence, this detail planning makes buying and selling a more exacting procedure rather than a method of averages. We feel that this detail procedure, that has been copied by many stores in the last 20 years, is a big factor in the growth of Rich's from ten million dollars in sales in 1940 to eighty million dollars in sales in 1957; also, it has been a big factor in increasing our inventory turnover, and increasing our dollar sales per square foot to where we exceed by 50 percent what is considered a good measure by many other stores.

EXPENSE AND SALES

Expense and sales must be closely coordinated in any business, but even more so in the retail industry which has more "peaks" and "valleys" than most industries. These "peaks" and "valleys" are instantaneously customer activated and the store that is not equipped to take advantage of these changes does not grow. In an attempt to "plan our work" and "work our plan," we budget all expenses by weeks, six months in advance, as soon as sales plans are formulated. These expense plans are approved by the Divisional Head and then submitted to the Operating Committee, who analyzes their effect and sets the profit plan for the store. (The Operating Committee consists of the executive officers of the company plus the 5 operating heads of the major divisions of the store.) These expense plans are then revised two months in advance, one month in advance, and then the personnel budgets are revised a week in advance by the Operating Committee at its weekly meeting to insure the adjusting of all expenses to actual conditions. The sensitivity and fast action of the Operating Committee to evaluate the correct business climate and its ability to keep the lines of communication connecting down to each manager and supervisor is the key to actually making a profit in these changing times.

The basic merchandise planning and expense budgeting procedures that we follow really are no different from what Frederick W. Taylor introduced in 1895 when he launched "Scientific Management." He invited management to dissect their entire operations into small segments, to analyze all phases of their operations, production and otherwise, and when maximum efficiency was conceived for each segment, to reassemble all the necessary component parts of the process into the most efficient operation possible. That, we try to accomplish through some of our methods that I have described.

Productivity Through Industrial Engineering Analysis

Industrial Design

by **MELVIN H. BEST**

President, Melvin Best Associates, Pasadena

NO ONE can deny that art is a great force in our society. It is one of the most durable forces of all times. For example, more of us are familiar with the work of Michelangelo, his sculpture and his paintings, than we are of the politics or economics of the time in which he lived. We are more familiar with the art of the early Egyptians than any other single item of their culture. Art and its great force is just as important today—not always the so-called "fine arts" of yesteryear, but also all of the "commercial arts" available for us to use in our modern world of commerce and industry. Most businesses today do make use of art in the selling or presentation of their product, whether it be through the familiar "ad" or whether it be in the appearance, shape or color of the products being sold.

INDUSTRIAL DESIGN

While industrial design, as a profession, is a relatively new field, we are well aware that over the years the best appearing or the best functioning product has sold over a competitor's products. Today, with specialized training

being available and the profession of industrial design being an established fact, all businessmen can make the force of art a force in their favor and thus turn this force of art into profit making. No one will deny, I am sure, that if a customer were deciding between two items of the same price (or even of varying price) that he would choose the one that "looked better" if appearance were any factor at all, or the one that "functioned better" if use were the criteria. This is where industrial design comes in. It considers both art and appearance, function and practicality.

CORPORATE IMAGE

A very interesting challenge offered corporations today is that of identity. We find in many corporations the need for a "corporate image"—a need for an image of the corporation as a single entity. There are many advantages to having a single corporate image. They have to do with the three "R's" (a different three "R's" to be sure): *Recognition*, *Repetition* and *Reputation*. A corporation today builds better and stronger with the use of these three "R's." In order to attain a singular image there must be continuity of trade mark usage, corporate colors, style of design of products and facilities, and all the phases of corporate "personality."

A SPECIFIC EXAMPLE

We are all aware of the use of industrial design today. Take the design program at International Business Machines, or Olivetti of Italy, or Container Corporation of America's use of the fine art in their ads, or General Dynamic's use of trade mark continuity for its many subsidiaries. But more than these specific examples of industrial design I would like to show a complete use, for a very effective job, of industrial design. The company I am referring to is the Ansul Chemical Company, a relatively small midwestern chemical company, that sought to counteract its actual size by special consideration of how it appears to its public. As do many managements today, Ansul has long taken advantage of the talents of specialized consultants, and in 1951 they hired an industrial design consultant whose task was to build this corporate image. The starting point was the trade mark. The resultant trade mark was a strong, readily identified symbol: a simple lower case "a." With this symbol approved and appropriate color scheme selected, all design activity was oriented to it: the products of the company, the graphics, the sales promotion, the company vehicles, every part of the company's activity. Through this use of recognition and repetition, reputation can be built and Ansul today has shown how it can successfully be done.

CONCLUSION

Industrial design is not limited in its use to that of product design, or trade mark design, or color coordination, or to case or package design. Today, thanks not only to the additional needs of the modern corporation, but also to the greater training and more comprehensive background of the industrial designer himself we find that profits and industrial design consultants often go hand in hand as corporations grow and as they recognize the need for this specialized consultant in another of our "specialized" fields in our "specialized" world of 1958.

Art can indeed be as great and durable a force in our world of industry today as it has been over the years in the history of mankind.

Pre-Production Planning

by **ARTHUR J. CASEBEER**

Planning Director and Production Manager, Cannon Electric Company, Los Angeles

MANY companies are finding that the mere allocation of a percentage of the sales dollar to Research and Development does not keep them in a competitive position. Much of the cream of new products advantage has already been skimmed off in many industries by progressive and hard hitting industrial research teams backed up by enlightened management. As a result, more and more companies are recognizing the necessity for including new product planning as a phase of over-all business strategy.

Let us consider the essentials of a new product development program, with particular emphasis on the preproduction aspects. In general, the following summary outlines basic steps of operation which have been found to be effective in companies with high reputation and good performance records on new products.

COORDINATION OF PRODUCT DEVELOPMENT

This is a basic management responsibility. Management has the responsibility to clearly define the direction of development and spell out company aims and goals so that each affected department can plot its course intelligently. Development programs are usually controlled at a high level, reporting to the chief executive, the top R & D officer, or the top marketing officer.

ORIGIN OF PRODUCT IDEAS

Programs should be established to develop product ideas to meet company objectives. Sales, research, and engineering personnel will usually develop the majority of successful ideas and it is vital that they work cooperatively. Provision should be made under the development plan for all areas of the company to participate. Suggestion plans and patent and invention plans have proven to be valuable in generating good ideas in some companies.

EVALUATION AND SELECTION OF IDEAS

This is usually accomplished in two stages, with the basic objective being to separate the wheat from the chaff as cheaply as possible. Preliminary screening is designed to eliminate those products which are obviously impractical or not in keeping with basic company policy. The ideas which survive are then put through a more comprehensive study, with the idea expanded to provide a basis for detail evaluation, usually under two subdivisions—"Technical Evaluation" and "Economic Appraisal."

Typical details under "Technical Evaluation" are—

1. Objective
2. Planned approach
3. Novelty, utility, and patent situation
4. Know how—inside or outside the company
5. Special requirements, such as reliability, environmental, or life testing
6. Safety
7. Likelihood of technical success
8. Pertinent references

Economic aspects are generally appraised under two sections. The first, "Market," includes the following:

1. Uses
2. Consumption
3. Probable sales and price
4. Competitive products, prices and manufacturers
5. Estimated growth curve
6. Profit estimates
7. Production volume, breakeven point

The second phase of economic appraisal, "Operation," usually includes the following:

1. Raw material availability and cost
2. Processing costs—labor and material
3. Plant capacity
4. Plant investment
5. Working capital
6. Compatibility with existing operations and product lines

From the answers to these questions all departments concerned can assess with a reasonable degree of confidence the chances of success or failure for a particular idea.

DEVELOP SPECIFICATIONS

Assign responsibility to conduct feasibility studies and preparation of specifications to cover the desirable market features and technical requirements for the idea. Determine the general over-all program to carry ideas through development and testing, and again review technical and economic justification.

DEVELOPMENT

Establish development projects for the product. Proceed with product development; explore methods, procedures, tests, and preliminary costs. Complete specifications and laboratory evaluation. Review technical and economic justification.

TESTING AND PRE-PRODUCTION PLANNING

Plan commercial tests to verify evaluation of product. Conduct in-use, production and market testing. Formulate plans for production and marketing. Make final decisions as to product acceptability and freeze design.

As the product goes into the development phase and into testing, it becomes increasingly important that key production personnel (Industrial Engineering, manufacturing, engineering and quality control) spend as much time as possible with the development and testing group to establish a basis for planning of production and quality control techniques. In many cases, the production representatives should assist in the preparation of the final cost and production estimates.

The final stage, of course, is commercialization where plans are finalized for production and sales. These programs are then initiated and the inevitable trouble shooting completed. Finally, we will check results from the commercial operations and, where necessary, make required improvements.

PROGRESS EVALUATION

Establish plans for control of costs and schedules. Provide for regular evaluation of progress of each new product development program.

The process of bringing new products into being is the result of many actions by many people in different areas of the company. There is danger that questionable ideas can be carried through a major portion of development before it is recommended that they be abandoned. It must also be emphasized that over-control may stifle ideas. The accounting section has a real responsibility to develop suitable control methods which are compatible with the project requirements.

The basic objective of these planning and evaluation steps is to select those ideas which have the best chance for ultimate success and to provide necessary funds and manpower for their development. Scheduling of a development program, while difficult to accomplish, becomes particularly important when the timing of new-product introduction involves a competitive advantage.

Continuing progress evaluation, coupled with enlightened management decision, provides a basis for securing better yield from funds expended for new-product development.

SUMMARY

From the foregoing, the following conclusions are drawn:

1. Sound new product development is the foundation of forward planning, as well as a necessary ingredient of most companies with high growth rates.
2. The new product program is a top management responsibility and should be organized as a top executive staff function.
3. Organization and degree of control should be adapted to the stage of progress in the development program. Suitable organization for product development is usually composed of a

team, with representatives from each affected department.

4. Continuing evaluation and control at each stage of development is vital and far more efficient than a single major screening effort.
5. Market requirements and opportunities are the primary considerations in product planning.
6. A definitive program, carefully planned and managed, will significantly improve new product results.

Facilities Planning

by **WILLIAM T. MORRIS**

Associate Professor of Industrial Engineering, The Ohio State University

THE HEADLONG advances which have characterized the profession of Industrial Engineering in recent years may leave us somewhat breathless, and suggest the need for a pause to consider the strategy and tactics which may now be employed in attacking management problems. This paper attempts to expose some of the strategic and tactical considerations which are involved in rationalizing a typical management decision. An example having to do with the planning of production facilities will be used. Specifically, the question of the appropriate number of machines for a production department will be examined. Approaches to this question are well known, thus we will not make any methodological contribution to the answering of the question. However, current engineering practice indicates that one confronts an important strategic choice between two very different sorts of approaches to the problem. It is our purpose here to make clear the nature of this choice, the factors to be weighed in making it, and the tactical considerations involved in the successful execution of whichever strategy is selected.

Like most engineering problems, the decision as to how many machines should be planned for a certain production department must be approached with three questions in mind. What data is available, or obtainable at reasonable cost (both in time and in money), which is relevant to the planning decision? What sort of model or logical structure can be constructed to predict the consequences and value of various policy choices? What can be "sold" to management? It is surely a platitude to assert that any strategy which is not compatible with realistic answers to these questions is of limited value to the engineer. Yet how often do we find people amassing reams of data for which they can develop no model or logical structure? How often do we come upon complicated mathematical models for which we could never obtain the necessary measurements in an industrial situation? How often do we suffer that frustrating experience of seeing a reasonable piece of engineering analysis find its way into a file, never to be retrieved? These are the problems of strategy to be examined below.

THE PROBLEM

A typical and important problem in the planning of production facilities is to decide on how many machines will be needed by a plant, or in this case, by a department. We have in mind a typical processing department which will contain similar machines, and through which a variety of products may pass. The considerations involved in this decision are obvious. One wants to know the capacity of the type of machine being considered, and the production which will be programmed for the department. Then the decision is a simple matter of planning enough machines to carry out the program, or simply matching "supply" and "demand," "load" and "capacity." The trick is, simply, to accurately predict the capacity of the machines and the magnitude of the production program. For purposes of discussion let us suggest two rather different approaches or strategies in rationalizing this decision. To give them names, we will refer to an approach which may typify much of engineering practice today as the *Standard Approach*, and to a somewhat more modern scheme as the *Advanced Approach*.

THE STANDARD APPROACH

Perhaps it is typical of many instances of this problem that the engineer looks for the following kind of information:

$\overline{T}_{ij}$ = the mean performance time for operation i on product j, measured in hours per unit of product
$\overline{D}_j$ = the mean demand for product j measured in units per production period
H = the number of hours in a production period
$\overline{E}$ = mean effectiveness factor; a decimal taking into account the usual personal allowances, machine down time, material shortages, scrapped production, etc., etc.

Having consulted the time-study department, the sales department, and various other sources for these average values, the engineer then performs the following simple calculation. The mean number of machines required by the department is given by

$$\overline{M} = \sum_i \sum_j \frac{\overline{T}_{ij}\overline{D}_j}{\overline{E}H}$$

where the summation is over products and operations within the department.

This is a fairly typical approach. Note, however, that even the data required here may be difficult to get in an actual situation, and additional simplifications may have to be made, leading eventually to nothing much more than a professional guess. The mathematical model is simple enough for everyone to use and understand. It represents the kind of calculation which most managements seem to find acceptable. The engineer inevitably feels a certain uneasiness at the gross oversimplifications which it involves. He well knows that performance times vary considerably, as any time-study sheet clearly shows. Estimates of production demand in most instances are subject to important errors. The events which are repre-

sented by the effectiveness factor also exhibit wide variation. For example, the scrap rate for a process, even when it is in control in the statistical sense, varies to an important extent. Let us assume for the moment that we can obtain data on all these kinds of variation. In the past one might have said, "We must content ourselves with a decision based on average values, since we have no mathematical model which includes this variation." Recently, however, the stimulus of Operations Research has made the necessary type of mathematical model widely available to engineers. The use of such a model is what we will call the Advanced Approach to the facilities planning decision.

THE ADVANCED APPROACH

The basic notions associated with this approach are as follows. If the performance times, demands, and effectiveness factors are subject to variation, then the actual number of machines required will be subject to variation. Realistically then, the management problem is to decide what number of machines should be installed to best meet this varying requirement. The result will be that in general there will be periods in which more machines are available than are required, and also periods in which fewer machines are available than are required. To the engineer developing a model for this decision it may be tactically important to note the analogy to certain inventory decisions (2). The manager must weigh these consequences, recognizing that as the number of machines are increased, the chance of having insufficient facilities will decrease, but the chance of having excess capacity increases. This leads to the tactical problem of measuring the costs of these events.

Tactically, also, the problem of describing the variation in the data must be faced. In order to exhibit an initial model let us assume that performance times, demands, and effectiveness factors are random variables which may be described by probability distributions. Thus let

$f(T_{ij})$ = probability distribution of T_{ij}
$g(D_j)$ = probability distribution of D_j
$h(E)$ = probability distribution of E

We assume that H is fixed by policy and is not subject to important variation. The validity of these assumptions is the subject of much familiar debate. For example, there has been extensive discussion as to whether performance times on man-paced operations can be described by simple probability distributions (3). If one uses the techniques of inferential statistics to forecast demand, then the resulting forecasts are subject to errors which may be modelled by probability distributions. The effectiveness factor may include machine delays, scrap production, etc., which are often described by the engineer in probabilistic terms. Clearly if these variables are taken to be random variables then the required number of machines, m, will be a random variable. Thus

$$f(m) = \alpha[f(T_{ij}), g(D_j), h(E)]$$

The tactical problem of finding the probability distribution of m may be approached in several ways. If the foregoing distributions are taken to be of analytically known form, then there are analytic methods for obtaining the distribution of m (4). If, however, the forms are not obtained, one might use the Monte Carlo method for obtaining an estimate of the distribution of m (1). This step can be a very difficult one in actual practice.

To develop a model for the decision one might proceed somewhat as follows. Suppose the following data is on hand:

$f(m)$ = probability distribution of actual number of machines required in a period
C_1 = fixed charges per machine per period

Considerable simplification of the model results if we assume that any production which cannot be completed during the regular production period is completed on overtime or by subcontracting. This avoids the mathematically difficult problem of accounting for production requirements which are carried forward from one period to the next. Assume for the moment that overtime is chosen. Let

C_2 = cost penalty (excess over regular time) per machine-period of overtime production

If we assume that management wishes to formulate a policy which will minimize expected costs, the criterion function may be written as

$$C(M) = C_1M + C_2\int_M^\infty (m - M)f(m)dm$$

where $C(M)$ is the expected cost of a policy of providing M machines.

By the methods of the calculus (which may present some tactical difficulties) we compute the optimal policy by setting

$$\frac{dC(M)}{dM} = 0$$

The result turns out to be the value of M, say M^* which satisfies the following relation.

$$\int_0^{M^*} f(m)dm = F(M^*) = \frac{C_2 - C_1}{C_2}$$

(We have assumed that M is a continuous variable, but this is easily corrected.)

Whether this model actually fits the real decision to a useful extent, depends on a number of crucial assumptions, some of which have been aforementioned. In addition we have assumed a linear cost structure, and implicitly a number of assumptions would be involved in the computation of the effectiveness factor. Fitting the model is, of course, a tremendous tactical problem.

STRATEGIC CONSIDERATIONS

Let us assume that the tactical problem of the model

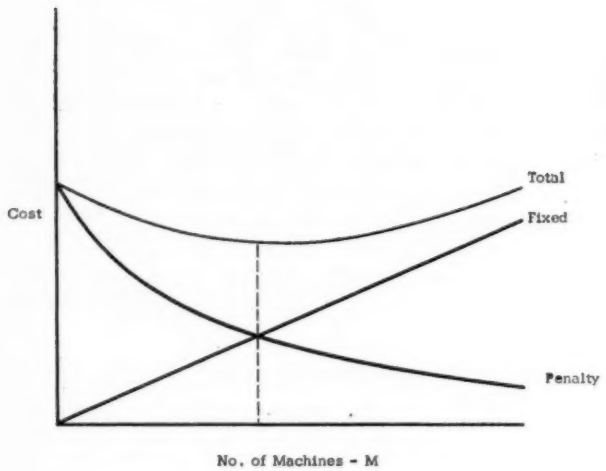


FIG. 1

could be dealt with, and examine some of the strategic questions which were suggested earlier. Clearly the Advanced Approach requires a large amount of data that may be difficult, if not impossible, to obtain in an actual situation. For example, it may not be possible to obtain performance time distributions for operations in the planning stage. If similar operations are already under way, the data may be available. If not, however, the only recourse may be to a synthetic time system which will roughly give the mean performance time. There may easily be such a large degree of uncertainty connected with the future production program, that no forecast can be made. One must also recognize those situations in which the data could be obtained but limitations of time and expense prevent it. It must be emphasized, however, that even if the data is not completely available the model itself may be of real value, as we indicate later.

The model itself presents a number of difficulties which we have outlined, but these may be overcome by anyone familiar with probability theory and the calculus. Actually there are some hidden difficulties of model construction underlying the effectiveness factor which has been used. Suppose, for example, that we have an operation that is under statistical control with respect to a particular quality attribute, and its mean scrap rate is p. One want to know how many pieces to make in order to get, say, D good pieces. Here again one may resort to averages and say that the average number of pieces to be made to yield D good ones is given by

$$\frac{D}{1-p}$$

Alternatively one might wish to be more accurate and say that the probability of having to produce $D + k$ pieces in order to obtain D good pieces is given by

$$\phi(D, k, p) = \left\{\frac{(D+k-1)!}{k!(D-1)!}\right\} p^k(1-p)^D$$

Thus the model itself may become quite complicated. Experience seems to indicate that it is worth while introducing probability distributions as we have done, but that very complicated distributions may perhaps go too far. The step from the Standard Method to the Advanced Method is nearly always warranted even if the data is not fully available. This step introduces the entire notion of establishing a fixed number of machines in the department, against a requirement which is actually subject to variation. Many feel that if the engineer makes explicit for management the sort of cost function given above, this is of considerable value as a basis for management decisions.

The final strategic consideration which was suggested was that of the analysis by management. This depends heavily on personalities and local factors of course, but something can be said about the benefits of the Advanced Approach. Let us suppose that the variables in our model

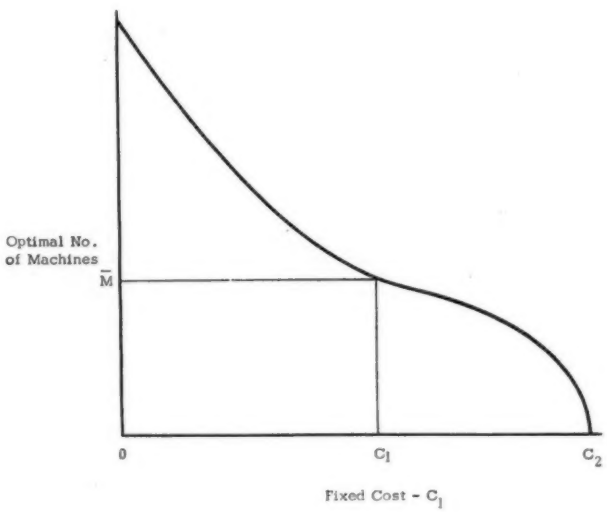


FIG. 2

are in fact subject to variation, as they are in many situations. The important question then is "How costly will be the errors in our plans if we base them on the average value approach?"

Figure 1 shows the form of a typical cost function and indicates the property of the optimal number of machines. Thus, if we plan for any other number of machines, total expected cost will increase. Figure 2 indicates the relation between the costs and the optimal number of machines. As C_1 becomes small relative to C_2, more and more machines should be planned for, and contrary-wise. If we neglect these costs completely and select a number of machines equal to the average requirement, this is equivalent to assuming values for C_1 and C_2. To the extent that these values are in error, the number of machines will be in error, and thus the cost will be increased.

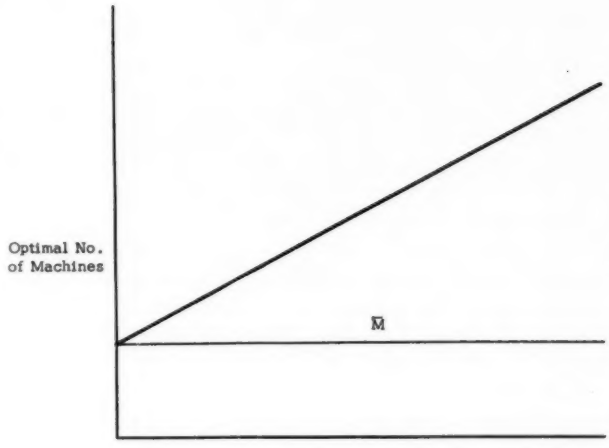


FIG. 3

Figure 3 indicates the result of failing to recognize the variation in the required number of machines. As the variation increases, the optimal number of machines increases, and thus the error made by planning for the average machine requirement also increases. Finally Figure 4 indicates the difference in total expected costs for the two methods as a function of the variation. Clearly, the more variation present in the machine requirement, the more costly it becomes to overlook variation and plan using average values. While the exact calculations which these curves suggest may not be actually carried out, it would seem that the general effects which they portray might well convince management of the importance of somewhat more advanced techniques in studying planning decisions.

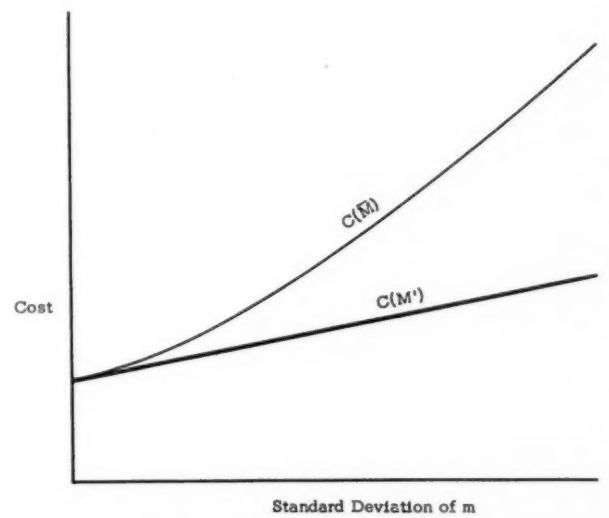


FIG. 4

This example of approaches to a management problem illustrates a number of typical strategic and tactical problems. The tactical problems form much of the curriculum of our engineering colleges. The strategic problems are less frequently discussed and seldom carefully considered. The conclusion with respect to the choice of strategy seems clear, however. What must be done is to match the input data with a logical structure, and then persuade management to consider the resulting analysis. This, like most such glib maxims, shines clearer in conversation than in execution.

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Economic Analysis of Automatic Equipment

by **RAYMOND R. MAYER**

Associate Professor, School of Business, University of Chicago

ANY ANALYSIS of automatic equipment is ordinarily inaugurated to determine whether this type of equipment should be adopted for use. The purpose of this paper is to present and discuss the factors to be taken into consideration in a study of this type. In this presentation, a certain number of assumptions and simplifications will be made in order to limit the scope of the topic and thus reduce it to manageable proportions.

To begin with, the only type of automatic equipment to be considered is manufacturing equipment. This means that such items as electronic computers and facilities employed in process industries will be ignored. Although some parts of the discussion will be applicable to these items, others will not, and no attempt will be made to classify the various statements accordingly.

Next, a very broad definition will be given to the term automatic equipment. For our purposes, it will be assumed that equipment is automatic relative to some other production facility and will ordinarily have the following three characteristics. First, its design is such that it is capable of performing many or all of the functions which would require the use of manpower under some other alternative; the consequence of this is that direct labor time per unit of output will decrease. Second, the equip-

ment's first cost, which includes installation, is such that the capital investment required will be greater than that required under some other alternative; there are cases in which this may not be true, but they are the exception rather than the rule. Third, its nature is such that the machine will be, relative to some other alternative, inflexible with regard to its adaptability to changes in product design and to the subsequent effect of these changes on required operations; in brief, the equipment is inherently a special purpose facility. Naturally, the degree to which a given piece of this type of equipment possesses these characteristics will vary. But although steps can be taken to minimize the undesirable consequences of one or more of these features, they can rarely be eliminated completely.

Given that the only equipment to be considered is automatic manufacturing equipment, as defined, the final limitations to be placed on this presentation is that the factors to be investigated are those which should be taken into consideration by the individual firm when confronted by an opportunity to invest in this type of facility. As a result, factors related to the overall economic and sociological implications of a widespread adoption of automation will be ignored. This does not mean that these broader implications are unimportant. However, they are considered to be outside the scope of this paper. In addition, a realistic approach compels one to accept the fact that the average company's primary concern is survival and profit maximization. To attain these goals it cannot afford to be governed in its actions by the effects of its decisions on the entire economy. These are matters which fall more naturally into the domain of government, organized labor, and the business community as a whole.

In summary, then, the problem confronting us in this discussion can be described as follows. A given manufacturing concern has a choice of two alternative methods of performing certain production operations. One of these methods requires the purchase of automatic equipment. What factors should enter the firm's evaluation of this alternative?

GENERAL CONSIDERATIONS

A reference to the factors to be considered in making an economic analysis of an alternative involving automatic equipment is a reference to the data that must be accumulated to permit description of this alternative. The description must appear in terms which will enable management to decide whether this alternative is the most economical one, that is, whether its selection will maximize profits. One form the description might take is the uniform annual cost of the alternative; another may be the rate of return on total and extra investment. For purposes of illustration in this presentation, it will be assumed that the description is to be made in terms of the equipment's annual cost. However, the same data would be required regardless of the method of analysis adhered to so long as the method is rational.

CAPITAL COSTS

In operating any production asset, a company incurs two kinds of costs. These consist of capital costs and operating costs. In those cases in which revenues are affected by the choice of alternative, these revenues can be looked upon as being negative operating costs.

The annual capital cost of owning any production asset consists of the annual depreciation charge, which should represent the amount by which the equipment decreases in market value, and the interest charge on the investment. To express this cost in terms of a uniform annual equivalent over the life of the facility, four items of information are required. These are: 1. the first cost of the equipment, 2. the service life of the equipment, 3. its terminal salvage value, and 4. the required rate of return.

The first cost of equipment should include the purchase price, delivery charges, and installation expense. Although this is as true for general-purpose equipment as it is for special-purpose equipment, in the latter case one of these elements tends to take on an added significance because of its magnitude. This element is the installation expense. It is not uncommon for automatic equipment to require an appreciable amount of time and effort to be expended in its erection. Also, one can usually expect to encounter many difficulties which must be eliminated before the equipment can be released for production; this is especially true if the asset is of special design and may be the first of its kind produced by the manufacturer. When considering the first cost of the facility, management cannot afford to ignore these charges, as it often can in the case of standard equipment, because of their magnitude.

The service life of the equipment should represent the useful or economic life of the equipment. Since this is not synonymous with physical life, management must bear in mind that not only deterioration but obsolescence play a role in determining the length of this period. In the case of automatic equipment, obsolescence will be the dominant of these two forces. Obsolescence can occur because of improvements in the design of new equipment or because of changes in the nature or design of the product to be produced. Although the occurrence of either of these two events is highly probable on operations being performed by special facilities, obsolescence due to product changes represents the greater risk. This is due to the fact that automatic equipment is inherently less flexible than non-automatic equipment and, hence, less adaptable to changes in product design. Admittedly, there are degrees of inflexibility, but whatever the degree, this factor must be considered. Unfortunately, some firms believe that they can control the rate at which obsolescence takes place. While they accept the fact that little, if anything, can be done to control changes in design of equipment to perform a given task, they are sometimes inclined to believe that they can govern the rate of change in product

design. This, of course, is a sound position to maintain in those cases in which competition or customer acceptance is not a factor to be considered, but this is rarely the case.

Therefore, in any estimate of expected service life for automatic equipment, the danger of obsolescence becomes extremely important, and the presence of this danger must be reflected in this estimate.

A third item of information, listed as being required to compute average annual capital costs, is the salvage value of the equipment at the end of its economic life. It is not uncommon for users of general purpose equipment to minimize the difficulty of making this estimate by assuming that the salvage value will be a certain percent, based on past experience, of the facility's first cost. The use of these existing ratios is undoubtedly not justified in the case of automatic equipment. Because obsolescence, due to lack of flexibility and outmoded design, is usually the controlling factor in determining the life of automatic equipment, management would probably be well-advised if instructed to be conservative in making this estimate —conservative in the sense that it would assume that there will be a limited market for the equipment and, hence, a relatively small salvage value.

The last item entering the annual capital cost computation is the required rate of return. The magnitude of this rate will be affected by a number of factors. Only one of these will be examined here, because its effect on the interest rate, unlike that of the others, will be influenced by the nature of the equipment being considered for procurement. This is the risk factor. In brief, one can say that the higher the risk the higher should be the required rate of return. There is little doubt that an investment in automatic equipment involves a greater risk than an investment in more flexible equipment. One reason for this has already been given, namely, the greater risk of obsolescence. Additional reasons will become apparent when other factors are discussed at a subsequent point in this presentation. But even if these other factors are ignored for the moment, the presence of obsolescence alone suggests that this added risk must be reflected in the analysis. Some companies may choose to provide for it in their service life estimates; others may choose to include it in their rate of return requirement; still others may choose to distribute it between the two. Nevertheless, when selecting the interest rate to be used in the study of automatic equipment, management must not lose sight of the fact that a great risk does exist, and this risk, if not compensated for in its estimates of other factors, must be reflected in the rate of return requirement.

RECURRING COSTS

It was mentioned that the second category of costs to be considered in any equipment acquisition analysis is operating costs. Although all of the following might not be relevant in any one case, operating costs would include such items as direct labor, direct material, indirect labor, maintenance and repairs, power, floor space, supplies, fringe labor costs, tool costs, scrap, property taxes, and insurance. For purposes of comparing investment alternatives, only those items whose magnitude will be affected by the choice of alternative are relevant and need to be considered. Since the magnitude of many of these items will be affected by the degree to which the equipment will be utilized in the future, it is necessary that management begin with an estimate of the assumed rate of production on the equipment during its service life. This assumed rate of production will not necessarily be the current level nor will it necessarily be the future level of output on some other facility that may be procured for the same purpose.

ASSUMED RATE OF PRODUCTION

There is every incentive to maximize output requirements on automatic equipment because of the effect this type of equipment has on the nature of the firm's costs. Relative to other kinds of facilities, automatic equipment ordinarily has a higher capital cost, which can be looked upon as being fixed. The only reason that a company will consider accepting this increase in fixed costs is because the operating characteristics of the asset are such that they will permit the realization of appreciable reductions in variable costs per unit. The most important of these variable costs is direct labor. Obviously, the more units produced per period, the more attractive automatic equipment becomes. It is for this reason that so much emphasis is placed on the need for attaining and maintaining relatively high levels of output to make an investment in automatic facilities attractive.

Because of the great advantages to be realized with automatic facilities from the standpoint of their desirable effect on direct labor costs, management will do well to precede any economic analysis of this type of equipment by a study of the steps that can be taken to increase the volume of work that will pass over the equipment.

One possibility that often presents itself is that components of various products can be redesigned and standardized to yield more economical production volumes. Naturally, if this has an adverse effect on customer acceptance of the products, this effect must be evaluated.

A second possibility is that some program can be inaugurated for increasing customer demand without decreasing the selling price per unit. Typical of such action would be increased advertising or market research in order to find and exploit new markets for the product. Again, the probable results would have to be evaluated in light of the cost of such programs.

It is important to note, however, that management could take advantage of either of these two possibilities regardless of whether or not special equipment is procured. Therefore, an increase in output and sales through these means is not necessarily dependent on the acquisi-

tion of automatic equipment. Instead, the opportunity of investing in this type of facility may serve only to suggest the desirability of increasing the required level of output. If the suggestion is adopted and production rates are increased as a consequence, there may be no revenue advantage to be associated with the special equipment. The cost comparison would be made on the basis of an increased rate of production, but this rate could be common to both alternatives.

As opposed to the case in which there need be no difference between the outputs and revenues of two investment alternatives, managment may find that an increase in output and revenue is feasible only if automatic equipmen is acquired. This could be true in the following set of circumstances. Because of the low variable costs per unit made possible by automatic equipment, management may decide that, in spite of relatively high fixed costs, total unit costs can be reduced appreciably if a certain level of output can be maintained. The reduction is such that management believes that a portion of it can be passed on to the consumer in the form of a lower selling price. Further, the elasticity of demand for the product is such that the reduced selling price will increase sales to the desired level. In this case, increased revenues are the result of a lower selling price which is the result of the cost reduction capability of the automatic equipment. Hence, one level of output would be associated with the automatic equipment, and a lower level with some other type of equipment. This is based on the assumption that the unit production costs with general purpose equipment would be such that no decrease in selling price would be possible and, hence, unit sales could not be increased.

In summary, therefore, management must make a thorough analysis of the factors affecting the rate of production to be associated with an automatic facility. And by no means should it adopt the attitude that only expanding markets provide a proper environment for the introduction of automatic equipment. Instead it should look upon the availability of automatic equipment as an incentive to take positive action to create the required markets. Of course, a risk always exists. Any significant decrease in the demand for the product involved will be accompanied by appreciably higher fixed costs per unit than would be experienced with less expensive equipment, and this might be accompanied by higher total unit production costs than would be experienced with non-automatic equipment. This added risk continues to exist to an appreciable degree even if one adopts the realistic attitude that direct labor costs are not as completely variable as they are assumed to be by most individuals. Nevertheless, it is important that management acknowledge the presence of this risk and reflect it in the estimated production rate or rate of return requirement.

RELEVANT OPERATING COSTS

In the most comprehensive case, which is the one to be discussed here, management will find that the rate of production on the automatic equipment will be higher than the output to be realized from a non-automatic facility. Where this is true, not only operating costs but revenues become a relevant factor because their magnitude is affected by the choice of alternative. There are a number of ways in which these revenue differences can be handled. Only one will be presented here.

The first step calls for estimating annual operating costs by using, as an assumed rate of production for each alternative, the volume of output which would be realized from the non-automatic facility and ignoring, for the moment, the added output and revenue from the automatic equipment. As mentioned earlier, not every item of operating costs will be relevant. Now, although it is impossible to say exactly which of these costs will be affected by the introduction of automatic equipment, it is possible to say that certain of these costs will, more likely than not, be affected. It is these items that will be considered. In addition, an attempt will be made to describe the direction in which they will probably act, that is, whether they will increase or decrease.

One of the more important of these operating costs is direct labor. There is reason to believe that the greatest benefit to be realized from the introduction of automatic equipment is the reduction of this expense. An estimate of the annual labor cost to be associated with the operation of any type of equipment calls for a knowledge of: 1. the annual level of output in units, which has already been mentioned, 2. the direct labor hours per unit of output, and 3. the wage rate per hour. Estimating labor hours per unit should be a fairly straight-forward procedure. However, the same cannot be said for hourly wage rates.

For a number of reasons, labor associates the introduction of automatic equipment with a need for higher wage rates to increase purchasing power, company training programs for those workers who must acquire new skills, earlier and more liberal social security allowances for those employees who are too old to learn new skills and must retire, increased unemployment compensation for those employees who are temporarily displaced, a guaranteed annual wage, longer vacations for all employees, and possibly earlier retirement for all employees. All these things will directly or indirectly increase the hourly cost of, not only direct labor, but all labor. If the company believes that labor will attain some or all of these goals, then it must include this increased cost in its estimates of future wage rates. It is sometimes argued that the introduction of one unit of automatic equipment will certainly not bring all this about. However, this one unit will probably be a step toward the creation of this situation and, hence, should bear its share of the burden.

Next to direct labor in importance is the factor of maintenance and repair. Just as one expects the cost of direct labor to decrease with the introduction of auto-

matic equipment, so one expects the cost of maintenance to increase. The two major components of this expense are the cost of material and labor. In estimating the required level of expenditure for the labor component of maintenance, management must consider not only the maintenance hours necessary to keep the facility in operation but also the labor cost per hour. Once again, as in the case of direct labor, the forces working toward an increase in future wage rates must be evaluated and reflected in assumed hourly rates for maintenance personnel. Further, it is in this area of maintenance and repair that the need for new skills becomes acute. Consequently, the firm must give consideration to the availability of these skills. Too often, one is left with the impression that only labor has something to lose if it does not possess the required skills. Actually, industry has a great deal at stake also, and the lack of required skills may delay the introduction of labor-saving equipment. Therefore, it is probably realistic to assume that, at some point, the introduction of automatic equipment must be preceded or accompanied by company training programs. These programs cost money and, therefore, must be looked upon as an expense, related to maintenance, that must be considered when describing the facility. Another point that can be made, in regard to maintenance expenses, is that the nature of the maintenance activity is such that the cost is not completely variable with changes in output. As a result, decreases in output will probably be accompanied by an increase in maintenance cost per unit. This added risk must be taken into consideration when making the analysis.

Although the current trend seems to be to place the emphasis on the effect of automatic equipment on direct labor, maintenance, and capital costs, there are a number of other relevant factors. The first of these is the effect of automatic equipment on raw materials and work-in-process inventories. Indications are that it is not unusual to find that the use of automatic equipment tends to reduce the level of these inventories. This results in a real saving, because decreased inventories ordinarily mean a reduction in storage costs, deterioration, obsolescence, and in the interest element of the carrying charge.

A decrease in raw materials inventories can usually be expected if the introduction of automatic equipment is accompanied by part standardization to yield economical production volumes. A secondary benefit may be that, if fewer kinds of materials and components will then be purchased but each will be purchased in larger quantities, quantity purchase discounts may be realized. Work-in-process inventories will probably be affected because, in most cases, automatic equipment may automatically transfer work from one station to another, perform a given operation faster, perform a number of operations simultaneously, and represent a more balanced production line than would otherwise be in operation. The presence of some or all of these factors will decrease process and material-handling times and, thereby, reduce the work-in-process inventory. At the same time, material-handling costs may be reduced. Further, these same automatic features will tend to minimize the amount of supervision and job instructions required.

Another item to be considered is the safety factor. The design of automatic equipment is usually such that it is much safer to operate because of more extensive use of remote control devices and less need for an operator to expose himself to the moving parts of the machine. Consequently, the facility can be expected to have a salutary effect on the frequency of accidents.

Also, in most cases, floor space requirements will be affected by the choice of alternative. With equipment of special design, it is not uncommon to find that this requirement is less than it would be if individual units of less specialized equipment were employed for the same series of operations. Of course, every reduction in floor space is not necessarily a saving. But if the released area is needed by the company at the time or will be needed at some future time, then a dollar value can be placed upon it.

Finally, consideration should be given to the equipment's effect on scrap. There is reason to expect that scrap will be reduced and quality of output improved with automatic equipment. This is the result of building the skill into the machine and narrowing the area in which human judgment and skill play an important role.

All these factors, that is, reduced inventories, less materials handling, reduced supervision, fewer job instructions, increased safety, less floor space, and improved quality, usually accompany the introduction of automatic equipment. They represent real cost economies that can be realized and, therefore, must enter the analysis.

On the other hand, there are additional factors which tend to place this type of facility in a less favorable light, and they also cannot be ignored. The first of these is down-time. Breakdowns become quite serious if the design of the equipment is such that a breakdown necessitates the shutdown of the equivalent of an entire production line. The result may be an inability to satisfy customer demand, or a need for overtime work or temporary multiple shift operation. This does not mean that this danger cannot be minimized by such things as a preventative maintenance program or an equipment design that permits, for example, the rapid replacement of an entire unit in which some component has failed. Nevertheless, the risk, even if reduced, is still there, and preventative measures do entail some expense.

In addition, it would not be unusual to find that electric power consumption will be affected. With automatic equipment, it can be expected to increase. Also, it would not be surprising to find that more planning is required to keep the equipment operating at the desired level, new job evaluations must be made, programming costs are

incurred with certain types of equipment, and that a reorganization of certain administrative and staff functions must take place. All these may be increased expenses that might not exist if some other kind of equipment were being utilized and, hence, they also must enter the analysis.

These then are some of the more important factors that should be considered when analyzing automatic equipment from the standpoint of operating costs.

NET REVENUE ADVANTAGE

The description does not always end at this point, because, as will be recalled, automatic equipment may be expected to yield a revenue advantage. Revenue then becomes a relevant factor in the analysis. However, if operating costs are estimated, as suggested, on the basis of output and sales made possible by both alternatives, then the advantage of an increased revenue from the automatic equipment must be described in terms of a *net* revenue advantage. This net revenue advantage is determined by, first, estimating what the total increase in dollar sales will be as a result of the firm's procurement of the special facility. Next, estimates must be made of the costs that will be incurred in the production and distribution of the additional units of product required to satisfy the increased demand. This cost will consist of the actual cost of manufacturing the additional units on the new equipment plus the incremental marketing and administrative expenses that will be incurred. The difference between the extra revenue and extra cost will be the net revenue advantage and will enter the analysis as a negative cost, if it is a positive figure. Coupled with the previously estimated capital and operating costs, this net revenue advantage permits management to describe the alternative completely in terms of total annual cost and compare this with the total for some other alternative.

SOME FINAL OBSERVATIONS

Actually, the factors to be taken into consideration in the economic analysis of automatic equipment do not differ in kind from those that should be considered when evaluating any equipment acquisition proposal. However, there is a significant difference in degree. Every effort has been made to point out this difference. For example, regardless of the nature of the equipment, future operating rates are important. However, because of certain economies made possible by automatic equipment, management may now find that it can and should take positive action to increase these rates.

The discussion of these factors also included observations related to the likelihood of these factors being relevant and their probable force and direction. This is not to say that they will be relevant in every case, nor that they will always have the same force, nor that they will always act in the same direction. Generalizations have been made with the full realization that there are always exceptions.

It will be noticed that the emphasis has been placed on what factors enter the analysis and that nothing has been said about how they enter the analysis. The last question can be answered only after a specific technique for comparing investment alternatives has been selected for use by the company. Some of the more rational available techniques include Joel Dean's discounted cash flow method, George Terborgh's MAPI formula, and Eugene Grant's uniform annual cost comparison. The principles underlying these methods are such that one or more of these techniques could be selected for making the actual analysis of automatic equipment. In other words, there does not appear to be a pressing need for the development of any new models to describe the case involving automatic facilities. The need that does exist, and always has existed, is for guides to simplify the estimation process, that is, for procedures which will enable management to express the factors in quantitative terms. Unless sound estimates can be made, the full benefits to be gained from the use of formulated techniques of analysis will never be realized.

Techniques of Profit Control

by **CHARLES A. BOGENRIEF**

Department Head, Industrial and Plant Engineering, Grayson Controls Division, Robertshaw-Fulton Controls Company

INDUSTRIAL Engineering plays an important role in controlling costs. Let's review a moment the definition of Industrial Engineering. "Industrial Engineering is concerned with the design, improvement and installation of integrated systems of men, materials and equipment, drawing upon specialized knowledge and skill in the mathematical, physical and social sciences together with the principles and methods of engineering analysis and design to specify, predict and evaluate the results to be obtained from such systems."

It is readily apparent from the definition of Industrial Engineering, providing that such overall concepts are carried out, that Industrial Engineering in an organization serves as the catalyst and provides the spark that will generate a sound control program.

AREAS OF COST CONTROL

There are roughly four major areas in which Industrial Engineering should operate to bring forth immediate results on a cost control program. These are as follows:

1. Job methods, job standardization and job evaluation.
2. Work measurement.
3. Operating cost controls and cost improvement.
4. Wage incentives and bonus plans.

These can be subdivided with many related endeavors

under each one.

You are probably thinking that these are old techniques of cost reduction, where are the new ones? I agree there are some new ideas and techniques developed to assist the Industrial Engineer in carrying out his job. Most of these are refinements and improvements on existing procedures. Let's use the old standbys to their fullest extent. These are the ones that can bring costs under control and increase profits.

Going back to the definition of Industrial Engineering, I think it is important to look at three specific words in that definition. These words are "to specify, predict and evaluate the results." Industrial Engineering must specify the requirements, predict the outcome and evaluate the results after the programs have been instituted to check to see the results approach what has been predicted.

JOB METHODS

The first step in a cost control program is in the area of job methods and procedures and job standardization. This phase is concerned primarily with the direct labor departments but many of the principles can be carried into the indirect sections. After all operations are method studied a written method should be provided for each operation. This written method should specify the conditions of the job, tooling, machines and equipment, feeds and speeds, and other necessary details to insure that in the future the operation will be repeated in exactly the same manner.

Quite often the same operation performed in two different areas of a plant will be tooled and performed quite differently. Through the job methods and standardization program such discrepancies can be eliminated.

WORK MEASUREMENT AND PERFORMANCE REPORTS

The next logical step is the measuring of the work content of the jobs. After the time standards have been applied we should establish a periodic performance reporting system, daily if practical. This performance report should be so tabulated that it shows a breakdown of the time spent by the employees on each operation or job. This report can be published to the operating department and posted in the area so the supervisor and his employees can see the results of the previous period's efforts. Such reports should be issued as soon as possible after the close of the work period.

OPERATING COST CONTROLS

These controls are not financial controls as used by accounting and cost departments, therefore, extreme accuracy is not as important as the availability of the information. Operating controls are not just a single record supplied to the supervisor for his use, in fact, the operating controls are made up of several individual reports and are usually issued weekly. In the beginning the controls can be used primarily to control labor expenditures since labor in a manufacturing department normally makes up a good share of the total expenditures in that area. Also labor is something the operating supervisor can control. If the controls are kept simple at their inception it is easier to obtain the supervisor's interest and cooperation in using them. There are several factors that are to be considered in operating controls to make them effective.

1. The cost information should be supplied to the supervisor while it is "hot." Information that is more than a few days old will not serve its purposes as far as the supervisor is concerned.
2. Operating controls must be based on sound time standards.
3. Operating controls must be simple, yet complete enough for the foreman to understand and be able to use.
4. The cost items included in the operating controls must be of such a nature that they are tangible to the operation which a foreman supervises. In other words, some of the overhead items, as used by accounting (such as rent, taxes, depreciation, and other innumerable items) have no direct tangible bearing on the effectiveness of management of the operating areas.

WAGE INCENTIVES

Wage incentives offer another means of decreasing operating costs to increase profit. As most of you know, a good incentive plan properly applied and administered should raise the level of output to somewhere between 120% and 130% of standard. Compare this to straight day work output of approximately 60% of standard and measured day work to somewhere around 80% of standard and you can see that there is a great deal to be gained by having a workable incentive plan.

Precautionary measures should be taken before instituting wage incentives. Careful preparation and detailed planning should precede their being introduced in an organization to assure satisfactory results. Briefly, here are the key features on incentives that any plan should embody:

1. The plan must be equitable in the pay off in direct proportion to the contribution by the employee. The plan must be easily understood and simple to calculate.
2. The plan should be tailored to suit the company needs.
3. Incentive pay periods should be as short as possible.
4. Incentives, wherever possible, should be on an individual basis.
5. The basis for a sound incentive plan is a guaranteed base rate, based upon job evaluation. Incentive earnings should never be a substitute for basic wages.
6. Management must provide an opportunity for earning a substantial incentive.
7. Time standards once applied should be guaranteed not to change unless there are changes in methods, machines, etc.
8. Provision must be made to review periodically the time standards and readjust them as changes become evident. Maintenance of time standards should be rigidly followed.

INDIRECT LABOR CONTROL

During the past few years there has been growing concern on the need for controlling the costs of indirect labor. Statistics show us the indirect workers are on the

increase when compared to the number of production workers. There are several reasons for this trend.

An important part of our cost reduction program should be controlling cost of the indirect departments. There are several problems encountered in this area that we do not find in the direct labor departments.

1. It is extremely difficult to get enough elemental times recorded to assure the accuracy necessary for a time standard.
2. It is often difficult to select a significant parameter.
3. As a rule, indirect labor is not effectively deployed unless there is a very close tie-in with direct labor.
4. The indirect labor supervisors are less methods conscious and cost conscious than those on the direct side.
5. Since more direct operations are of team or group nature it is difficult, in fact, almost impossible, to apply individual work measurement.
6. Indirect groups are usually made up of higher skilled employees than those found in the direct departments. Many of the jobs are the craft type. As a rule the employees in this group are usually more sensitive and have quite different temperaments than those in direct production. This necessitates a little different approach to work measurement in these departments.

COST IMPROVEMENT PROJECT

There is a definite need in most companies for a continuing cost improvement program. This is an excellent way to reduce excessive costs. This group is usually spearheaded by the Industrial Engineering department, however, such a group can be teamed with other personnel as the situation requires.

The primary function of the cost improvement project is to review existing operations or processes with respect to tooling, methods, equipment, process and the like; and recommend, institute and check the results of significant changes that will substantially reduce the cost of the operation.

In the average organization this cost improvement group should be able to justify their existence by putting into effect savings that will exceed their salaries by as much as three or four times each year.

Here again, planning is necessary if we are to obtain the full benefits from this group. It is necessary to prepare a priority list of projects that are to be re-engineered. Complete and detailed records should be kept on all engineering time spent, plus the proposed cost of the changes needed. Also, actual costs must be kept of the installation of the improvements. And finally, a summary report must be made of each of these projects as to the net outcome of the savings.

A report of these savings is an excellent way to provide top management the results of a cost reduction program.

COST CONTROL REPORTS TO TOP MANAGEMENT

It is necessary with profit or cost control programs to have a direct means of reporting the results to top management. Management has a multitude of duties and responsibilities and its time is strictly budgeted. Consequently, long detailed drawn out reports cannot be read and assimilated as they should be. Therefore, we should proceed with caution on the management reporting techniques. It is better to present the information in a brief concise, factual and conclusive manner covering a very few paragraphs of written material. One of the easiest ways to bring to the attention of top management these results is to prepare simple charts and graphs of the results.

SELLING THE PROGRAM

In all the phases of cost control programs one fact is quite evident. The programs must be sold and kept sold if they are to continue.

There are three groups to sell:

1. Top management.
2. Line and staff supervision.
3. The employees.

There are many different ways to accomplish this. Before embarking on a new project it is well to set up an informal training program for the groups to which the endeavor is to be directed. I have found that classroom discussion is a very easy way to accomplish this. Another point to remember is that this training should reach all groups that are to be affected by the program.

One of the best training grounds for supervisors is in the Industrial Engineering department. I firmly believe all line and staff supervisors should spend a considerable period of time in the Industrial Engineering department, learning the fundamentals of Industrial Engineering. By the nature of the operation of the Industrial Engineering department, Industrial Engineers pretty well cover all phases of the operation of business. Their work with cost accounting, production control, scheduling, timekeeping, personnel, manufacturing, sales and most other functions enables the Industrial Engineer to have the best all-around knowledge on what makes an organization "tick."

OVERALL MANAGEMENT PLANNING

The control of costs (profits) requires full time participation of management. Too often management tends to "quit worrying" about profit if business is good or a healthy backlog of orders is on file. This is dangerous. If a slack period does strike they are totally unprepared to act.

Management must plan not only for the control of profit at today's market but also for tomorrow's market. Whether business is in an upturn or downturn situation, management must know what costs should be at any level and be able to maintain a reasonable profit. A sound cost (profit) control program will enable management to pinpoint deficiencies so that they may be overcome before it is too late.

Organization Planning

by **CHARLES F. ROWBOTHAM***

Long Range Planning Coordinator, Rocketdyne, Division of North American Aviation, Inc.

ORGANIZATION Planning is certainly not new. Men have planned and they have organized as long as human beings have joined together to pursue a common goal. In any company that is growing, decentralizing or changing in any way, organization structuring is going on whether we call it Organization Planning or not, or whether or not there is a staff group to help in shaping the organization structure. Consequently, what is really new is that Organization Planning has been recognized as a specific identifiable management "tool" or "skill," and that Organization Planning staffs are being established to provide management with the specialized help, the formal systematic techniques necessary to focus attention on and to help solve the organization problems involved in accomplishing the objectives of the enterprise.

The executive who wishes to establish an Organization Planning staff in his company, or the engineer entering this staff work today is in an enviable position compared to the "pioneer" of yesterday. At his disposal is a tremendous amount of published material resulting from the extensive research and study in this field in the past few years. Some of it is good, and some not so good. From these materials one can learn the "Why" and the "How" of Organization Planning.

Next, and most important, is the question, "Does it Work?" Our experience in Organization Planning staff work at North American Aviation can help show how principles and techniques can be successfully used in actual industrial situations.

NORTH AMERICAN AVIATION

First, I would like to give you a thumbnail sketch of North American Aviation as we find it today. Our company includes a General Office, six operating divisions each headed by a vice president and general manager, and Navan Products, Inc., a wholly owned subsidiary. North American Aviation and Phillips Petroleum Company jointly own Astrodyne, recently established to develop solid propellant rocket engine systems.

Sales for Fiscal Year 1958 will be approximately $800 million. Approximately 53,000 employees are on the North American payroll. Our operating divisions differ widely in size and in products, ranging from the Los Angeles Division with approximately 18,000 employees to Atomics International with approximately 2 000 employees. Los Angeles Division products include the F-100 Super Sabre, the X-15 Rocket-Powered Research Airplane, the new B-70 Long Range Supersonic Bomber, and the F-108 Advanced Interceptor. Columbus specializes in Navy airplanes. Missile Division devotes itself primarily to complete missile and missile booster systems. Autonetics specializes in electro-mechanical navigation and fire control equipment. Atomics International builds nuclear reactors. Rocketdyne, with approximately 12,000 employees, concentrates on liquid propellant rocket engine systems and produces the engine systems currently operating in our nation's large missile programs.

COMPANY ORGANIZATION

That completes the thumbnail sketch, so let's see how we have "organized" to do Organization Planning. Our Corporate Director of Organization Planning, reports to the Vice President of Administration. Some of you may be curious about Salary Administration and Management Development. In our company they are considered personnel functions and report to the Corporate Director of Personnel Administration. Organization Planning functions have been established in each of our six operating divisions. For example, at Rocketdyne, our Administrator of Organization Planning reports to the Director of Management Services. Management Services is staff to the General Manager and includes Organization Planning, Operations Analysis, and Procedures and Forms. It should be noted here that the primary relationship between Corporate Organization Planning and Division Organization Planning is one of policy guidance. Any direct operating instructions to a division must have the concurrence of the division General Manager.

The Corporate Organization Manual is one of the means used for policy guidance. It contains position descriptions of the principal corporate executives and of the division general managers, corporate organization charts and division master charts, organization policy statements, and corporate committee charters. Position description programs are underway in all operating divisions.

A close-up of the division will best illustrate the ways in which an Organization Planning staff can help line management fulfill its basic responsibility for organization. Management in the missile business today must adjust to a set of challenging conditions. Primarily, these conditions are a rapidly advancing state-of-the-art; relatively short production runs at low rates; and accelerated programs which necessitate producing deliverable engines concurrent with Research and Development programs. The organization which can live with the missile industry today has to be quick on its feet—nimble, alert, and packed with short, fast, effective lines of communication. In addition, it must be stable enough to survive shocks and elastic enough to meet emergencies.

Our top management, working closely with Organization Planning, thoroughly analyzed this problem and re-

* Formerly Administrator of Organization Planning in the General Offices of North American Aviation, Inc.

cently developed the Program Management Team concept to supplement our functional line organization. The Program Management Team is a superstructure, by means of which the talent of the line organization can be focused on the individual product.

Top management, in fact, every manager, realizes that planning his organization is an integral part of his management duties, that each organizational problem must be approached with an analytical attitude—dig in, get the facts, and then develop the structure which best solves the particular problem. Stereotyped thinking must be replaced with an open mind, and often a bold and imaginative approach is required to survive in today's rapidly changing conditions.

ORGANIZATION AND FUNCTIONS

As another example of our flexible approach to organization, we have developed a new concept to replace the traditional "line and staff" terms. These new terms, *staff, service, operating,* we have found, are simple and easily understood. Staff indicates those functions which assist an executive in carrying out personal responsibilities which he cannot delegate. Management Services (including Organization Planning) as staff to the General Manager is an ideal example of such a function. Service functions are those functions which control and condition the environment in which operating functions carry out their jobs. Operating functions are those activities without which the company cannot achieve its objectives. These relationships can be better understood by visualizing our organization chart. At the top are the Vice President and General Manager, the Assistant General Manager, and the staff functions of Public Relations, Management Services and Program Management. Service functions are at the next level and they include Industrial Security, Personnel, Finance, Plant Engineering and activities falling in the area of Business Administration. Operating functions, Engineering, Material, Manufacturing, Quality Control and Service, are spread across the bottom of the chart. Of course, within an operating or service function we can use the staff, service, and operating terms to identify components within the function.

We have established a formal written procedure for the processing of organization changes, organization announcements, and organization charts. Our concept of "compulsory advice" makes it mandatory that service and operating functions consult with Organization Planning before organization changes are made. But, and this is a "key" distinction, their advice need not be accepted, although it generally is. Final responsibility for his organization must remain with the manager concerned.

Here's the way it works in practice. When Organization Planning is called in on a proposed change, a two-way exchange of "know-how" results. The head of the function supplies detailed knowledge of the operations, information about the personalities concerned, and goals and objectives of his group. Organization Planning focuses attention on the organization principles involved, and usually develops a series of charts showing possible alternative solutions, listing advantages and disadvantages of each. When a mutually agreeable solution has been worked out, it is presented to management for approval by the head of the function concerned, not by Organization Planning. If Corporate level review is required (and there is a written procedure listing the changes which require Corporate review) after coordination at the division level is completed, then Organization Planning "carries the ball" and makes a formal presentation to the Corporate Director of Organization Planning. He in turn coordinates the proposed change with all concerned corporate executives. Here it must be emphasized that at both the division and corporate levels Organization Planning is not a "control." It can only review, analyze, advise, and persuade. It can never accept or reject. This, we feel, is a management responsibility which cannot be delegated.

ORGANIZATION PLANNING GROUP

Our Organization Planning group consists of the Administrator and his secretary. Another man or two may be added as the work load builds up. However, we feel that if the group is too large there is the inherent danger of over-emphasis and of accumulation of a collection of miscellaneous staff functions. We also feel that placing Organization Planning on the General Manager's staff keeps it independent of the functions it serves, which is a necessary ingredient to an atmosphere of mutual trust and respect.

Personal relationships between Organization Planning and the people it serves are just as important, we have found, as knowledge of organization principles and techniques. A face-to-face relationship of complete trust, confidence, mutual respect and understanding is a "must." In Organization Planning work we are always dealing with human beings, their reputations, and their careers, not with machines or brick and mortar. Consequently, Organization Planning by remote control just isn't satisfactory.

SUMMARY

Let's put the things we have learned from our experience into a digest form so they will be easier to remember:

1. Assist your "line" managers in carrying out their responsibilities for organization by establishing a full-time Organization Planning staff to systematically focus attention on this critical area.
2. Keep your Organization Planning staff small, free from miscellaneous staff duties, and located at the highest possible level in the organization.
3. Establish a formal procedure for the processing of organization changes, using the concept of "compulsory advice."
4. Concentrate on the development of mutual trust and confi-

dence between Organization Planning and the people it serves.

5. Above all, when an organization change is being considered, dig in, get all the facts, and then analyze them carefully in developing possible solutions. Avoid rigid, inflexible application of rules and principles.

I should like to conclude by pointing out that we are entering an era of tremendous growth and accelerating technological change, namely, the space age. Lt. Gen. Irving, Air Force's Deputy Chief of Staff for Materiel, dramatically stated that engineers and scientists serving the Air Force and industry must progress as far in the next five years as we have in the past fifty (1). *Business Week* points out that our whole economy will nearly double by 1975 with our gross National Product rising from today's $434 billion to $835 billion in 1975 (2). Annual Research and Development spending doubled in the period 1953-1957 and should double again by 1960, creating new products, new processes and even entire new industries.

Consequently, the factors that have caused the rapid increase in the use of Organization Planning staffs in the past (expansion, decentralization, diversification, competition, and the impact of technological change) will be even more significant in the future. Hundreds of new companies will establish Organization Planning functions, and hundreds of positions in Organization Planning will have to be filled. Because of the need for thinking that is both analytical and imaginative, and both people-oriented and systems-oriented, I assume many of these positions will be filled by Industrial Engineers.

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Management Planning and Control

by **JOHN D. McFADDEN**

Staff Consultant, Management Services Division, Ernst & Ernst, Los Angeles

THE OBJECTIVE of my discussion is to examine, in the light of modern management concepts, the broadening areas of business endeavor for both the Industrial Engineer and accountant. We will accomplish this objective by doing three things:

1. By placing reporting in its proper perspective in relation to planning.
2. By reviewing the elements of planning which make reporting possible.
3. By examining the roles which the engineer and accountant must play in planning and control.

CONTROL REPORTING IN ITS PROPER PERSPECTIVE

General business conditions today find most companies faced, on the one hand, with greater competition and price resistance, and on the other hand, with constantly increasing labor and material costs.

The result of the combination of these factors is a decrease in company profits. Therefore, company executives are confronted with more and more decisions which must be made faster than ever before; moreover, they find today's decisions have far greater impact on the continued successful operation of their companies. It is only natural, then, that as a basis for the decisions which must be made, there is a demand for more and better financial and operating control reports.

It is only natural, too, that management will look, initially, to the financial function of the business for this reporting. Generally, the man directly involved will be the controller.

Development of a good control reporting program can be a tough problem. A going business generates great quantities of financial data, but only portions of it are relevant to effective control. Reporting which is intended to bring about management action must be selective if it is to succeed, not too voluminous, and not routine.

Rather frequently you will encounter the business executive who is complaining about the lack of reporting in his company. "I can't seem to find out what's going on in my own company," he states. A red-faced, indignant controller interrupts and says, "You're getting a complete set of financial statements every month, just the same as the other executives in the company." "Do you mean that thick black book?", asks the business executive, "Yes," replies the controller. "Well," replies the business executive, "as I was saying, I just can't seem to get control information in this company. . . ."

In some respects, you cannot help but sympathize with the controller in this situation. In the development of a reporting system, more often than not, he is faced with the same problem as a police department which has been requested to apprehend a tall, thin culprit who was short and fat. In other words, reporting must not be too much without being too little.

In searching for a solution to his problem, the frustrated controller might do well to let his mind wander outside of the business world, and dwell for a few moments on an item of every day usage. This item is a road map.

A road map has little value for an individual who doesn't plan to travel. Conversely, it can be of great value to the individual who does plan to travel, and greater value when the individual has a specific destination in mind. For the traveler, the specific destination which he has in mind will dictate the choice of road map. Then, using the selected road map as a guide, the traveler will begin his journey. As he proceeds to his destination, the traveler will quite frequently verify his progress in

relation to the map by the use of check points, such as towns and highway signs.

A light might flash in the controller's mind at this point. He might go back over his last thought, "verify his progress in relation to the map by the use of check points, such as towns and road signs." He might very well crystallize his thinking now on his immediate problem, adequate control reporting.

In its proper perspective, financial control reporting should be the town and road sign used by management to check its progress in relation to a predetermined plan. The plan will dictate the amount and kind of reporting which will be necessary. The reporting system will be only as good as the plan which management develops.

Being an impetuous individual, the controller suddenly picks up the telephone and calls the executive who has been complaining about the lack of control information. The controller opens the conversation by saying "I agree with you, you're not getting good control information, but I just decided whose fault it is. It's yours, because you haven't developed a company plan of operation on which I can report."

With this approach, the controller may or may not keep his job, but certainly he hit the nail on the head. A system of reporting for management control can best be developed only in relation to a management plan for operation.

I like to refer to the plan of operation as profit planning, and with the complexities in today's business operation, both the engineer and accountant must contribute to profit planning, if it is to be successful.

PROFIT PLANNING

Our next consideration, then, should be to review the elements which constitute a good profit plan. These elements are:

1. Recognition of the fact that gross profit is contingent both on volume at a specific cost, for instance at standard, and also on variations in actual manufacturing operations from those standards.
2. Definite assignment of the responsibility for gross profit based on standard cost. The sales department may be charged with the responsibility for gross profit at standard, which means, then, that pricing is that department's responsibility.

   On the other hand, manufacturing may be charged with the gross profit responsibility, meaning that manufacturing controls pricing. In that event, the sales department is responsible only for sales volume.

   Failure to make this designation of responsibility has weakened, and always will weaken, management control over variations in gross profit.
3. Development of the sales forecast as the basic plan to provide gross profit at standard, and to serve as the measure of sales department performance.
4. Use of standards to plan product costs and anticipated performance, and to measure and control actual manufacturing costs in relation to plan.
5. Recognition of the necessity for using standards, adjusted for anticipated levels of performance, as the basis for product pricing. If the standard is the basis for cost control, and variances are anticipated, then pricing must also be based on the adjusted standard, or it is possible to operate at planned performance levels and still lose money.
6. Operating budgets for each organizational responsibility.
7. Capital equipment budget.

Let's look now in more detail at each of those elements of profit planning where engineering or accounting must be instrumental in its development, considering first the sales forecast.

THE SALES FORECAST

The profit planning activity in a typical company usually begins with individual product selection. This is normally accomplished through a product selection committee which reviews a sales department request for a particular kind of product, and considers a market survey of potential for the product. If the item appears promising, the committee will initiate an engineering and manufacturing feasibility study to determine if the company can make the product, and if it can be made, to determine the estimated standard unit cost.

I believe that a broadened scope of Industrial Engineering activity today should include the responsibility for this feasibility study. I believe that Industrial Engineering's first contribution to profit planning must be to guard against the possibility that a product which is only apparently profitable will be selected for manufacture.

This possibility exists where substantial tool making, mold making, or some other initial cost, applicable to individual products will be required, and will not become part of the direct product cost. Single purpose machinery is another example of initial cost.

The danger here is that a product may be priced to result in a 15% profit based on the estimated standard unit cost. However, with a substantial initial cost, that 15% profit will be realized only when the number of units sold yields enough profit to absorb the initial costs and still provide a profit which will be 15% of the selling price of total unit sales.

After initial costs and standard manufacturing costs are estimated, the Industrial Engineer should construct a product break-even chart, relating his estimated costs to the total estimated selling price for the number of units forecasted. Based on his chart, the engineer may recommend a higher selling price, or he may recommend the elimination of the item from consideration.

While product selection is usually continuous, the preparation of a sales forecast of total volume for a planning period is periodic. A preliminary sales forecast represents the combined best thinking of the selling and marketing functions of the company as to the kind of products, quantities and selling prices which the company can realistically expect to experience in the planning period.

While total volume of the forecast is one of the essential elements for evaluation, it is probably not the

most important. The product mix within the total volume forecast is particularly significant for control and evaluation purposes. Here again, is an area where I think, today, the Industrial Engineering capability is essential in developing the final sales forecast.

Product line designations usually represent a grouping of products which are similar in nature, and therefore in method of manufacture, or they may represent a grouping of products which, because of market potential, have similar profit margins.

Whatever the basis for classification, the important considerations are first, that each product line will usually have a different profit margin, and secondly, that each product line will provide different capacity utilization.

Therefore, the finalized sales plan must represent maximum planning for the utilization of plant capacity. The planned mix must provide a balanced work load. To the extent that market conditions allow, preference must be given to those product lines with the lowest variable costs to produce, and, therefore, with the highest margin for absorption of fixed costs.

Obviously, economic conditions are not always such that a company can definitely plan and attain its desired mix. On the other hand, if the most desirable mix is not planned, and sales effort oriented in that direction, a desirable mix probably never will be obtained.

This evaluation of the preliminary sales forecast to determine the adequacy of the product mix from the production standpoint is a natural area for the Industrial Engineering capability as I have previously mentioned.

STANDARD COSTS

Let us now focus our attention on the use of standards as an element of planning. I want to concentrate our discussion in this area on two points, namely, using standard costs for profit planning, and secondly, the necessity for cooperation between the accountant and engineer in order for the company to experience maximum benefits from the use of a standard cost program.

We have seen that another of the elements of profit planning is the recognition by management of the fact that gross profit is contingent upon volume at a standard cost, and upon the variance from standard in the manufacturing operation. This means, then, that there must be in existence basic standard data which, when product specifications and the manufacturing processes are known, may be used to develop both part and assembled product labor hour costs.

There must be, too, the ability to project, with reasonable accuracy, the anticipated variances in departmental labor performance. These anticipated variances are important to profit planning in that standard product costs should also be used as the basis for product pricing. If anticipated variances are not included in product pricing, some planned gross profits will never materialize.

These profit planning activities must be contributed by the Industrial Engineer.

Let's consider for a few moments the maximization of benefits from the use of a standard cost program.

First, let me state that I think that cooperation and mutual understanding of each other's problems will enable the Industrial Engineer and accountant, working together and not in opposite directions, to assist management in profit control. Too often I suspect that the accountant is concerned primarily with inventory valuation in his use of standards, while the engineer is concerned only with current work measurement. Each goes merrily on his way, and each will be giving management a different picture on the efficiency of direct labor. With the resulting confusion, it is no wonder that little profit control can be exercised, and that many managements would just as soon throw out a standard cost program.

The operation of a successful standard cost program requires both the engineer and the accountant. Clashes in objectives for the use of standards by each party seem to me to arise principally in connection with the desire to make mid-year changes in standards, or to adjust for some abnormal event.

The engineer must understand that where substantial inventories are involved, the cost to revalue such inventories at an interim period is usually prohibitive. The accountant must understand that it is to his advantage, from a reporting and analytical standpoint, to go out of his way to accumulate and distribute additional information which will enable the engineer to properly evaluate current performance.

It is my opinion that this mutual appreciation of the other's problems is best exemplified by a system of reporting which provides management with a reconciliation of unadjusted labor performance, as recorded by accounting records, to a true level of performance as seen through the engineer's eyes. This reporting should also provide management with a clear designation of responsibilities for labor variances.

This use of standard costs requires additional work by both parties. For the engineer, it requires the development of a system whereby a production foreman may initiate a labor deviation whenever he loses production time through no fault of his own. These deviation requests must indicate the function responsibile for his loss of time, and that function must accept the responsibility. It must be the responsibility of engineering to review these deviations and investigate their justification. It must also be their responsibility to accumulate all deviations by cause during the reporting period, and furnish this information to the accountant.

The contribution by the accountant to this system involves the dual valuation of production counts where substantial revisions in standards have been affected because of method changes. Because of inventory considerations, these revisions cannot currently be picked up in the

cost standards, but true measurement requires their recognition.

As I have stated, this type of cooperation requires additional work. There is, however, one important beneficiary, and that is management, because of the control information which it receives.

THE OPERATING BUDGET

Let's turn our attention now to another element of profit planning, the operating budget. The purpose of the operating budget is to convert the sales forecast into production budgets, then to project the production budget into direct labor and material cost budgets, and, finally, to develop departmental expense budgets based on the level of activity indicated by the direct labor budget. In non-productive departments, the operating expense budget will be related more directly to the general level of operation indicated by the sales forecast, rather than to a derivative of the forecast, such as the direct labor budget.

With particular regard to the manufacturing departments, the operating expense budgets, to be of real value in profit planning and control, must be developed on a variable basis. With variable budgets, it is possible to establish departmental expense allowances at any given level of activity. With this type of budget program, break-even analysis for profit planning considerations is simplified, and from a control standpoint, the amount of indirect expense which should be incurred at the level of production actually attained, may be determined and compared to actual expenditures.

The development of a variable budget requires that all indirect expenses be categorized in one of these classifications:

1. Expenses which vary directly with the level of production, such as supplies.
2. Expenses which vary with production on a semi-variable or step basis. Many indirect labor classifications are examples of this type of expense.
3. Expenses which are fixed by management decision.
4. Expenses which are fixed by nature, such as depreciation, taxes, etc.

It is normal in most organizations to find the responsibility for budget development and administration centralized in the financial division of the company. Sound budget philosophy also dictates that each department of the company will be responsible for the preparation of its own operating expense budget. The usual procedure is for the budget manager to consult with various departmental managers, and to assist them in any way possible in the development of their budget.

I think, however, that it is a smart budget manager who, recognizing his deficiencies in many of the technical aspects of a manufacturing operation, seeks a bridge to cross the gap between the knowledge of what he wants, in this area, and the ability to get it. The bridge over this gap is Industrial Engineering.

I have found Industrial Engineering capabilities valuable in this area of profit planning for these reasons:

1. Because of educational and experience backgrounds, the engineer is more qualified, generally, than is the accountant to assist the various manufacturing department managers in the preparation of a budget. This is particularly true in the area of development of variable and step variable expense ratios.

   While it is true that the accountant or budget manager can develop variable ratios by analysis of past history, it is also true that those ratios will be only as good as that past history. Inefficiency will only be perpetuated by the use of historical ratios.

   In my book, the best variable expense ratio is one that is based on engineering study.

   This same thinking applies even more strongly to step variables. The best step variable for indirect labor is a manning table, and who besides the engineer should develop manning tables?
2. The second reason why I consider the Industrial Engineer invaluable in this area of profit planning is the element of human relations which is so important in budget considerations.

   Because of day-by-day contact on other matters, manufacturing department managers will usually have more confidence in, and therefore cooperate better with, the Industrial Engineer than they would with someone from another division of the company.

THE CAPITAL EQUIPMENT BUDGET

Let's focus our attention now on the last element of profit planning which we will consider, and that is the Capital Equipment Budget. Just about every company with which I have come into contact is restricted in the amount of its working capital. It must, therefore, be highly selective in the ways in which that working capital is used.

Expenditures for plant and equipment always represent a substantial cash requirement, and management, therefore, must be highly selective in the equipment purchased. A company's profit plan must include the total amount which it plans for capital expenditures, and the plan must insure that each of the expenditures will do a job for the company.

The development of the capital equipment budget should be the responsibility of the Industrial Engineer. He should both initiate proposed purchases and be responsible for evaluating the requests for equipment purchases initiated by others.

Each piece of equipment recommended for purchase must include a statement of purpose, such as replacement, new product, or cost reduction. If the purchase is for new products or cost reduction, there must be included a dollar estimate of additional revenue or cost savings, most generally expressed as either a return on investment, or payout period.

In my opinion, the responsibility of the engineer with regard to each new purchase of equipment doesn't end until he has furnished a report of actual savings experienced, usually in the form of revised standards, at some specific interval after the equipment has been put to use.

CONTROL REPORTING

Now, for a moment, let's think back to the conclusions arrived at by our frustrated controller in his thinking about adequate control reporting. We recall that he concluded that good control reporting could come about only when there was a company plan of operation against which he could report. He also concluded that the company plan should dictate the kind of reporting necessary.

Let's assume now that management called the controller's bluff, and established a program of profit planning along the lines which we have discussed. Now that management wants good financial control reporting; the question is what should it consist of?

There is a twofold objective for financial control reporting:

1. To present in summary form, in terms of organizational responsibility, a comparison of actual operations to the essential elements of the company's profit plan, and to record variances therefrom.
2. To provide management with as much or as little supporting detail as it may wish to review. Each variance set forth on the summary statement must be supported by more detailed reports which analyze the variance down to the individual indirect expense classification on departmental expense budgets.

This type of reporting is designed to provide for management by exception.

SUMMARY

In conclusion, I want to summarize these points:

1. In today's economy, management needs more good control information.
2. Good control reporting can come about only through profit planning.
3. The various elements of profit planning, and control through planning, require ever increasing contributions by the Industrial Engineer and Accountant, if such planning and control is to be successful.

Linear Programming

by **WILLIAM KARUSH**

System Development Corporation, Santa Monica, California

IN ORDER to suggest the range of applicability of the theory of linear programming, it may be useful to first describe a theory that deals with a more general type of mathematical model—we may call the broader theory "mathematical programing."

In mathematical programming we are confronted with a situation in which a set of "activities" is available to us, say n of them, $i=1, 2, \cdots, n$. The activity level x_i is a number which specifies the quantitative level at which activity i is to be carried out, and a *program* is a total list of activity levels $x_1, x_2, \cdots, x_n$. Each such program must satisfy certain conditions in order that the program be physically realizable—such a program is called *feasible*. These feasibility conditions may occur for various reasons depending upon the particular application—a program may consume a certain amount of a given resource and the amount of that resource may be limited; a program may produce a certain commodity and it may be that the amount produced must meet a certain minimum requirement; etc. Associated with each program is a single number which is the *objective measure* of the program (cost, profit, total production, etc.)—the value of this measure varies with, that is, is a function of the program, the so-called *objective function*. The purpose of mathematical programming is to determine among all feasible programs, one which is *optimal* in the sense of the objective measure, that is, one which yields the most favorable value of the objective function.

The notion of activity as used in this description is allowed the most general possible interpretation. For example, the various activities of a program may refer to the production of distinctly different commodities in a single, fixed time interval, or they may refer to the production of the same commodity in different time periods which make up a total planning interval; they may also refer to a mix of activities classified both with respect to type and time.

Linear programming deals with models of mathematical programming in which the feasibility conditions can be expressed as linear relations among the activity levels $x_1, x_2, \cdots, x_n$, and the objective function is also linear in these variables. A more general way to describe this type of model is as follows: we specify a *unit* activity (a set of constants that state the amount of each resource consumed, amount of goods produced, etc.) and calculate the effect of an arbitrary activity level x_i as proportional to x_i. It is implied in this description that the effects of the various activity levels are independent of each other, e.g., if x_1 consumes amount Ax_1 of a given resource, and x_2 consumes amount Bx_2 of the same resource, then the combination x_1, x_2 consumes Ax_1+Bx_2.

Linear programming is a widely used analytical tool which has proved its effectiveness in many applications by providing the decision-maker with a quantitative basis for choice of action. In this paper we shall discuss the fundamental concepts of this tool and its mathematical techniques of solution; this will be done chiefly through illustration and general mathematical description.

AN EXAMPLE OF A LINEAR PROGRAMMING PROBLEM

In order to fix our ideas, let us take a simple example of a linear programming problem which will be adequate for illustrative purposes without bogging us down with details.

In this problem we have three activities, $i=1, 2, 3$, which we may think of as the production of three different commodities. The production of each commodity requires the consumption of three different resources, which we may think of as machine time on three different machine

classes. Unit activity for activity 1 is the production of a single commodity—unit production requires five time units on machine class 1, three on machine class 2, and one on machine class 3. Thus, with the unit activity we associate the column vector P_1 where

$$P_1 = \begin{pmatrix} 5 \\ 3 \\ 1 \end{pmatrix}.$$

Unit activity for $i=2$ and 3 are represented by vectors

$$P_2 = \begin{pmatrix} 2 \\ 5 \\ 3 \end{pmatrix}, \qquad P_3 = \begin{pmatrix} 3 \\ 2 \\ 4 \end{pmatrix}.$$

For example, production of a single commodity 3 requires four time units on machine class 3. A *program* is specified by three production levels x_1, x_2, x_3 where, of course,

$$x_1 \geq 0, \qquad x_2 \geq 0, \qquad x_3 \geq 0. \qquad \text{Eq. 1.}$$

The machine time required for a program x_1, x_2, x_3, is symbolically represented by

$$x_1P_1 + x_2P_2 + x_3P_3.$$

This stands for the three separate machine times

$$5x_1 + 2x_2 + 3x_3,$$
$$3x_1 + 5x_2 + 2x_3,$$
$$x_1 + 3x_2 + 4x_3.$$

We now impose the limitation that only 105 units are available on machine class 1, 65 on machine class 2, and 115 on machine class 3; these will be the only restraints imposed. Thus,

$$\begin{cases} 5x_1 + 2x_2 + 3x_3 \leq 105 \\ 3x_1 + 5x_2 + 2x_3 \leq 65 \\ x_1 + 3x_2 + 4x_3 \leq 115. \end{cases} \qquad \text{Eq. 2.}$$

Mathematically speaking, the program x_1, x_2, x_3 is *feasible* in case it satisfies the relations Eq. 1. and Eq. 2.

It remains to specify the *objective function*. Suppose that a unit of commodity 1 yields a profit of \$55, a unit of 2 a profit of \$50, and a unit of 3 a profit of \$45. Then the total profit of the program x_1, x_2, x_3 is

$$F(x_1, x_2, x_3) = 55x_1 + 50x_2 + 45x_3. \qquad \text{Eq. 3.}$$

All the conditions of the problem are now specified (see Table 1) and the problem of finding an *optimal solution* has the following precise mathematical form: determine values x_1, x_2, x_3 which

$$\text{maximize } F(x_1, x_2, x_3),$$

with the variables subject to the conditions Eq. 1. and Eq. 2.

This is a typical, though simple, linear programming problem. In the most general linear programming we may have any number of variables $x_1, x_2, \cdots, x_n$, instead of just three. These variables are typically required to be nonnegative, just as in Eq. 1. Instead of three linear relations in three variables as in Eq. 2., we may have any number of linear relations in the n variables (the number of relations is *not* required to equal the number of variables, as it happens to do in Eq. 2.). Furthermore, these linear relations need not be of the $\leq$ type; they may involve a mixture of $\leq$, $\geq$, and $=$. (For example, in Eq. 2. we might have required equality in the second relation, namely, that all available machine time be used on machine class 2.) Finally, in the general case, we are to optimize a linear objective function $F(x_1, x_2, \cdots, x_n)$ of n variables—this optimization may mean maximization of F as above, or it may mean minimization of F, as might occur if the objective function involved cost instead of profit.

TABLE 1

Machine Time for Unit Production. Also Shown, Unit Profit and Available Machine Time

	Commodity 1	Commodity 2	Commodity 3	Available Time
Machine Class 1	5	2	3	105
Machine Class 2	3	5	2	65
Machine Class 3	1	3	4	115
Unit Profit	55	50	45	

The example above illustrates a certain inadequacy of the method of linear programming that might well be pointed out here. The matter arises in applications where set-up time or set-up cost is important. In the example, we assumed that machine time was proportional to production level—this ignored the fact that machine time for *positive* production level is a term proportional to the level *plus* a constant (set up time), while machine time for *zero* production is zero. As long as we are certain that all production levels will be nonzero in the optimal solution, then our model is adequate. We may simply subtract set-up time from available machine time and use the remainder as the available time. But if the optimal solution can involve zero values of some of the x_i, then our model is not correct, unless set-up time is negligible in comparison with running time. To summarize: there is no direct way of incorporating set-up time or similar types of discontinuous costs into linear programming models—when these costs are important we must resort to special devices such as solving the problem under various assumptions on zero activity levels and comparing the various optimal solutions obtained from these problems.

METHOD OF SOLUTION—THE SIMPLEX METHOD

Thus far we have seen what a linear programming model looks like when it is set up in mathematical form. The next item of business is how to go about obtaining the solution of the mathematical problem. We shall use the example given by Eq. 1., Eq. 2. and Eq. 3. as an illustration.

A program x_1, x_2, x_3 may be visualized as a point in three-dimensional space, using the usual three-dimensional coordinate axes. A *feasible point* is one that satisfies the six inequalities (Eq. 1. and Eq. 2.—the inequalities Eq. 1. specify that a feasible point lies in the positive octant, while each of the inequalities Eq. 2. specifies that it must be on one side of a given plane. For example, the first inequality states that a feasible point lies on one side of the plane given by the linear *equation* $5x_1+2x_2+3x_3=105$—the same side that the origin lies on. Altogether, the six inequalities Eq. 1 and Eq. 2. describe a polyhedral set of points in three-dimensional space whose boundary consists of six planar faces, the three coordinate planes and the three planes described by the equations corresponding to Eq. 2. Thus, in geometric terms, the linear programming problem is to find a point in the polyhedral set which gives the largest value to $F=55x_1+50x_2+45x_3$

The value F for any feasible point may also be given a geometric interpretation. Draw the half line in three-dimensional space which begins at the origin and continues on through the point (55, 50, 45). For any feasible point (x_1, x_2, x_3), draw the perpendicular from that point to the half line —suppose the perpendicular meets the half line at the point P. Then $F(x_1, x_2, x_3)$ is simply a certain constant factor times the distance from the origin to P. Thus, an optimal point is one in the polyhedral set which is farthest from the origin in the direction of the half line.

The polyhedral set of feasible points has a finite number of *extreme points*, i.e., corner points where three faces meet; it is not difficult to see intuitively that one of these extreme points must be optimal, i.e., lie at a maximal distance from the origin along the direction determined by the coefficients 55, 50, 45 of the objective function. If this is so, we can find an optimal point by finding the extreme points, evaluating $F(x_1, x_2, x_3)$ for this finite number of points, and picking one for which F is largest.

Although this geometric description for finding an optimal point is helpful for providing insight into the nature of the problem, it does not supply an effective computational method for ferreting out the optimal point. In essence, the *simplex method of solution*, which we shall now describe, is a systematic technique for moving from one extreme point to another, step by step, until an optimal point is reached.

In order to apply the simplex method to the example at hand we first modify the example by changing conditions Eq. 2. to equalities. This is done by introducing nonnegative *slack variables* x_4, x_5, x_6 and expressing Eq. 2 as

$$\begin{cases} 5x_1 + 2x_2 + 3x_3 + x_4 = 105. \\ 3x_1 + 5x_2 + 2x_3 + x_5 = 65 \\ x_1 + 3x_2 + 4x_3 + x_6 = 115. \end{cases} \quad \text{Eq. 2'.}$$

Adding the slack variables amounts to introducing certain artificial unit activities

$$P_4 = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}, \quad P_5 = \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix}, \quad P_6 = \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}. \quad \text{Eq. 4.}$$

The first activity, for example, is interpreted as wasting one unit of time of machine class 1. In terms of the six variables, the problem is to maximize the linear function Eq. 3. with the nonnegative variables subject to Eq. 2'. It is not difficult to see that this is the same problem as before, with only formal modification. Notice that F is a linear function of the *six* variables in which it happens that the coefficients of x_4, x_5, x_6 are all 0. Although we seem to have complicated the problem by adding new variables, we have properly prepared the problem for the application of the simplex method.

In the new form, a point $(x_1, x_2, x_3, x_4, x_5, x_6)$ is *feasible* in case $x_i \geq 0$ $(i=1, 2, \cdots, 6)$ and the equations Eq. 2' are satisfied. We *begin* the simplex method by choosing a feasible point in which three of the coordinates x_i are 0—such a point is called a *basic solution.*[1] The easiest basic solution to pick is

$$x_1 = 0, x_2 = 0, x_3 = 0, x_4 = 105, x_5 = 65, x_6 = 115,$$

and, of course, corresponds to the trivial feasible program of producing no commodities at all. This selection is indicated in the left column of Table 2 where we have listed the nonzero activity vectors P_4, P_5, P_6 and their corresponding levels 105, 65, 115. The vectors P_4, P_5, P_6 are the *basic vectors* for this initial solution.

TABLE 2

Initial Basis P_4, P_5, P_6

	$\downarrow P_1$	P_2	P_3	P_4	P_5	P_6
← P_4 105	5	2	3	1	0	0
P_5 65	3	5	2	0	1	0
P_6 115	1	3	4	0	0	1
Profit Difference	−55	−50	−45	0	0	0

Profit $F=0$

In order to improve our basic solution, i.e., pass to a basic solution with a larger value of F, we begin by filling in the entries in the main body of Table 2.[2] *These entries tell us how to express each of the activity vectors P_i in terms of the basic vectors.* For example,

$$P_1 = 5P_4 + 3P_5 + 1P_6.$$

[1] Here, the term "solution" does not refer to the solution of the entire problem, i.e., the feasible point which maximizes F, but rather to a nonnegative solution of Eq. 2'—in other words, to a feasible point. The notion of "basic solution" is the counterpart of "extreme point" in our geometric description. Our method of solution will thus take us from basic solution to basic solution.

[2] A table such as Table 2 is often referred to as a "tableau" in linear programming terminology.

That is,

$$P_1 = 5\cdot\begin{pmatrix}1\\0\\0\end{pmatrix} + 3\cdot\begin{pmatrix}0\\1\\0\end{pmatrix} + 1\cdot\begin{pmatrix}0\\0\\1\end{pmatrix}$$

$$= \begin{pmatrix}5\cdot 1 + 3\cdot 0 + 1\cdot 0\\5\cdot 0 + 3\cdot 1 + 1\cdot 0\\5\cdot 0 + 3\cdot 0 + 1\cdot 1\end{pmatrix} = \begin{pmatrix}5\\3\\1\end{pmatrix},$$

which is correct, according to the original definition of P_1. It is a simple matter to fill in these coefficients when the basic vectors have the simple form shown in Eq. 4.—in this case, the entries are nothing but the components of the activity vectors. However, if it happened that the three initial basic vectors were not of the form shown in Eq. 4., then a little more work would be involved in writing out the initial tableau; to determine the entries under P_1 we would have to solve three equations in three unknowns, say a, b, c, represented symbolically by

$$P_1 = aP_4 + bP_5 + cP_6.$$

By means of Table 2 we can decide which of the vectors P_1, P_2, P_3 it is profitable to bring into the basic solution in place of one of the present basic vectors P_4, P_5, P_6. The decision is based upon the "cost differences" in the last row of the table, which are computed as follows: for P_1

profit difference

$$= 5\cdot(\text{unit profit for } P_4) + 3\cdot(\text{unit profit for } P_5)$$
$$+ 1\cdot(\text{unit profit for } P_6) - \text{unit profit for } P_1 = -55.$$

Similarly, the profit differences for P_2 and P_3 are computed relative to the given basis P_4, P_5, P_6—the profit differences for the basic vectors always equal 0. The profit difference serves to compare the value of an activity vector as a linear combination of the basic vectors with its value in its pure form. *If this difference is negative for a nonbasic vector, then it is worthwhile introducing it as a new basic vector,* replacing one of the present basic vectors by it. Otherwise, no gain is realized by introducing this vector in the basis.

Examining the last row in Table 2, we see that it is worthwhile to introduce any one of the vectors P_1, P_2, P_3—as a simple rule we agree to introduce the vector with highest negative difference (or, in general, anyone of the vectors with highest negative difference, if there is more than one such). Thus, P_1 is to be introduced, as indicated by the arrow at the head of the P_1 column.

The next item to decide is at what level, x_1, to introduce P_1 and which one of the basic vectors to replace—these two issues are decided simultaneously, and the answer is based upon the condition that no activity level be negative. Let y be the unknown level for P_1; according to the entries under P_1, for each unit of P_1 introduced we must subtract 5 units of P_4, 3 units of P_5, and 1 unit of P_1—this is necessary in order to retain Eq. 2.′ Thus P_1 at level y requires P_4 at level $105-5y$, P_5 at $65-3y$ and P_6 at $115-y$. Hence, y must satisfy all the conditions

$$105 - 5y \geq 0, \qquad 65 - 3y \geq 0, \qquad 115 - y \geq 0,$$

i.e.,

$$y \leq 21, \qquad y \leq \frac{65}{3}, \qquad y \leq 115.$$

We now choose y as the largest number satisfying these relations—this is,

$$y = 21.$$

This reduces P_4, P_5, P_6 to the respective levels 0, 2, 94. Thus, P_4 is removed from the basis (as indicated by the outgoing arrow) and we begin the second tableau, Table 3, with the new basis P_1, P_5, P_6 at the levels 21, 2 and 94. By using the profit function we compute that the new profit value is 1155—this is an increase of 1155, which is precisely what we expected, since we introduced 21 P_1's and each P_1 was worth a profit difference of 55, according to Table 2.

Having decided on the new basis for the second tableau, we must now fill out the entries in the body of Table 3, which express each of the activity vectors as a combination of the new basic vectors. Fortunately, there is a simple algorithm for modifying the entries in any one tableau to get the next tableau. Consider the first tableau, Table 2. Take the entry at the intersection of the incoming vector P_1 and the outgoing vector P_4—namely, 5. Divide every entry in the row of the outgoing vector by this number 5 —this gives the row 1, $\frac{2}{5}$, $\frac{3}{5}$, $\frac{1}{5}$, 0, 0 in the new tableau following the new basis vector P_1. In Table 3 we also fill in the columns under the basic vectors P_1, P_4, P_5 with appropriate 0's and 1's. Now let us fill in the column under P_2. We already have the coefficient, $\frac{2}{5}$, of P_1. The *new* coefficient of P_5 is obtained as the *old* coefficient of P_5, 5, less $\frac{2}{5}$ times the old P_1 coefficient of P_5, 3;

$$5 - \frac{2}{5}\cdot 3 = \frac{19}{5}.$$

Similarly, the coefficient of P_6 is the old coefficient, 3, less $\frac{2}{5}$ times the old P_1 coefficient of P_6, 1;

$$3 - \frac{2}{5}\cdot 1 = \frac{13}{5}.$$

Interestingly enough, the new profit differences can be computed in the same way, e.g., the new P_2 difference is the old difference, -50, less $\frac{2}{5}$ times the old P_1 difference, -55;

$$-50 - \frac{2}{5}(-55) = -28.$$

The remaining columns, P_3, P_4, are filled in in the same way. The profit differences for the new basic vectors P_1, P_5, P_6 are 0, of course.

TABLE 3

Second Basis P_1, P_5, P_6

		P_1	P_2 ↓	P_3	P_4	P_5	P_6
	P_1 21	1	2/5	3/5	1/5	0	0
←	P_5 2	0	19/5	1/5	−3/5	1	0
	P_6 94	0	13/5	17/5	−1/5	0	1
	Profit Difference	0	−28	−12	11	0	0

Profit $F = 1155$

Examining the profit differences in Table 3, we see that it would be unprofitable to introduce P_4, but profitable to introduce P_2 or P_3—we choose P_2, with the larger difference. Introducing P_2 at level y, means reducing P_1, P_5, P_6 to

$$21 - \frac{2}{5}y, \qquad 2 - \frac{19}{5}y, \qquad 94 - \frac{13}{5}y,$$

respectively. The largest value of y which is possible, keeping these levels nonnegative, is 10/19; this leads to the replacement of P_5 by P_2. Using the technique described above, we construct Table 4 out of Table 3.

TABLE 4

Third Basis P_1, P_2, P_6

		P_1	P_2	P_3 ↓	P_4	P_5	P_6
	P_1 395/19	1	0	11/19	5/19	−2/19	0
←	P_2 10/19	0	1	1/19	−3/19	5/19	0
	P_6 1760/19	0	0	62/19	4/19	−13/19	1
	Profit Difference	0	0	−200/19	125/19	140/19	0

Profit $F = 1169\ 6/19$

Further computational details are not necessary, since the process is repetitive. Notice that in going from Table 4 to Table 5 we drop the vector P_2 in favor of P_3 despite the fact that at the stage of Table 2 it appeared more profitable to introduce P_2 than P_3. This is not an uncommon phenomenon in this simplex procedure, to introduce a basic vector which is later replaced. Our process is analogous to climbing to a peak step by step by taking the longest step we can each time—actually, it might be advantageous to take a short step sometimes to be in a better position for a longer step later. Since we cannot know this in advance, we follow the reasonable rule of the longest step each time, longest step here meaning introducing the vector of greatest profit difference at that time.

In Table 5 the "slack" vector P_4 comes into the basis. If the activity level of P_4 is y, then we have as the activity levels of P_1, P_3, P_6,

$$15 - 2y, \qquad 10 + 3y, \qquad 60 - 10y.$$

The point to be noticed here is that the second of these three expressions is *always* nonnegative (for nonnegative y) and hence does not restrict the value of y; only the first and third expressions restrict y. This situation arises often in applications of the simplex method—in introducing a new basic vector we need only be concerned with the *positive* coefficients in the column under that vector.

Table 6 shows the optimal solution,

$$x_1 = 3,\ x_2 = 0,\ x_3 = 28,\ x_4 = 6,\ x_5 = 0,\ x_6 = 0,$$

Profit = 1425.

Thus, the optimal solution is to produce 3 of commodity 1, 0 of commodity 2, and 28 of commodity 3; this program results in using only 99 units of the 105 available

TABLE 5

Fourth Basis P_1, P_3, P_6

		P_1	P_2	P_3	P_4 ↓	P_5	P_6
	P_1 15	1	−11	0	2	− 3	0
	P_3 10	0	19	1	− 3	5	0
←	P_6 60	0	−62	0	10	−17	1
	Profit Difference	0	200	0	−25	60	0

Profit = 1275

on machine class 1, but in using full capacity on machine classes 2 and 3.

We recognize the optimality by the fact that the profit difference row contains no negative elements. A mathematical theorem in the theory of linear programming assures us that when this situation obtains we have reached an optimal solution, a fact which is intuitively evident. We are also assured that by following the simplex algorithm we shall reach the optimal stage in a finite number of steps.

We conclude this section with some further general remarks concerning the simplex method. A linear programming model may begin with the linear restraints on the nonnegative variables expressed as a mixture of the $\leq$, $\geq$, $=$ types; to apply the simplex method it is necessary to convert these restraints to equalities. This is easily done by adding a slack variable in the case of $\leq$, and subtracting a slack variable in the case of $\geq$. When the restraints are all in the form of equations, there are typically more variables than equations, say m equations and n variables with $m < n$ and a *basic solution* comprises

TABLE 6

Optimal Basis P_1, P_3, P_4

	P_1	P_2	P_3	P_4	P_5	P_6
P_1 3	1	1.4	0	0	0.4	−0.2
P_3 28	0	0.4	1	0	−0.1	0.3
P_4 6	0	−6.2	0	1	−1.7	0.2
Profit Difference	0	45	0	0	17.5	2.5

Profit = 1425

a selected set of m of the variables, with the remaining $n-m$ put equal to 0. The simplex technique begins with a particular basic solution. In applications, it is usually easy enough to find an initial basic solution—if this is not the case, more formal mathematical methods are available for the start of the algorithm. Finally, we mention the problem of degeneracy. This situation arises when one of the variables in the basis has the value 0, and may cause the simplex method to run into difficulty. This situation is not typical, but when it occurs there are special techniques for handling it.

THE TRANSPORTATION PROBLEM

There is an important subclass of linear programming models known as transportation models for which an optimal solution can be obtained in an especially simple manner. To illustrate the nature of the problem, consider a situation involving two factories F_1, F_2 and three warehouses W_1, W_2, W_3. The two factories produce a given commodity at known levels and the outputs are shipped to the three warehouses which have known requirements. Shipping is possible from any factory to any warehouse, and the problem is to determine how much to ship from each factory to each warehouse so as to minimize total shipping costs. Suppose the numerical data is given by Table 7; i.e., F_1, F_2 produce 80 and 60 units respectively, W_1, W_2, W_3 require 60, 30 and 50 units respectively, and the unit shipping cost for any factory-warehouse pair is as shown in the body of the table. Let

x, y, z = amount shipped from F_1 to W_1, W_2, W_3, respectively

u, v, w = amount shipped from F_2 to W_1, W_2, W_3, respectively.

Then we have

$$x, y, z, u, v, w \geq 0, \qquad \text{Eq. 5.}$$

$$\begin{cases} x + y + z = 80 \\ u + v + w = 60 \\ x + u = 60 \\ y + v = 30 \\ 3 + w = 50. \end{cases} \qquad \text{Eq. 6.}$$

The problem is to minimize the cost function

$$F = 2x + 2y + 4z + 3u + 2v + w$$

subject to Eq. 5. and Eq. 6.

Let us phrase the problem more generally. Suppose that there are m origins O_i, $i=1, 2, \cdots, m$, and n destinations D_j, $j=1, 2, \cdots, n$. Suppose that a_i units are available at O_i, and b_j units are required at D_j; we are assuming that $a_1+a_2+\cdots=b_1+b_2+\cdots$. Suppose that c_{ij} is the cost of shipping a single unit from O_i to D_j. Let

$$x_{ij} = \text{amount shipped from } O_i \text{ to } D_j.$$

Then we have $m \cdot n$ variables x_{ij} which must satisfy the feasibility conditions

$$x_{ij} \geq 0 \qquad \text{Eq. 7.}$$

$$\begin{cases} \sum_{j=1}^{n} x_{ij} = a_i \\ \sum_{i=1}^{m} x_{ij} = b_j \end{cases} \qquad \text{Eq. 8.}$$

where

$$\sum_i a_i = \sum_j b_j.$$

The problem is to minimize

$$F = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij}.$$

Equations in Eq. 8. number $m+n$, but there is one dependent equation among these $m+n$—since the sum of the first set in Eq. 8. yields the same equation as the sum of the second set of equations in Eq. 8. namely,

$$\sum_{i,j} x_{ij} = \sum_i a_i = \sum_j b_j.$$

For this reason a *basic solution* consists of $m+n-1$ activities x_{ij} (not $m+n$), i.e., the number of origins plus the number of destinations, less one.

The number of variables can increase quite rapidly with the number of origins and destinations, and this can lead to a computational job of some magnitude in solving the transportation problem by the simplex method. Fortunately, because of the particular form of the feasibility equations, Eq. 8., a great simplification can be achieved in the simplex technique which reduces the magnitude of the work considerably.

The simplified technique will be illustrated by means of the 3-origin, 4-destination problem shown in Table 8. In this case, $m=3$, $n=4$, so that a basic solution consists of $m+n-1=7-1=6$ shipping activities. To begin the solution algorithm, we use the initial basic solution shown encircled in Table 9. This solution is easily derived by means of the "south-east" rule. Start in the upper left-hand corner and assign as much of the available amount at O_1 as possible to D_1. This results in 60 units from O_1 to D_1, and leaves 10 units at O_1. We move "east" to D_2 and assign the remaining 10 at O_1 to D_2. We next move "south" to O_2 and assign 20 of the available amount at O_2, to make

TABLE 7

Transportation Model—2 Factories, 3 Warehouses Shipping Costs, Production Levels and Requirements

	W_1	W_2	W_3	Production
F_1	2	2	4	80
F_2	3	2	1	60
Requirements	60	30	50	Total 140

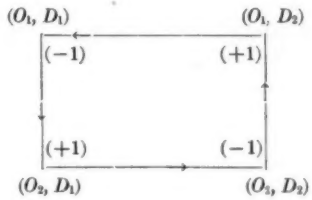
TABLE 8

Transportation Model—3 Origins, 4 Destinations

	D_1	D_2	D_3	D_4	Available
O_1	2	3	2	1	70
O_2	3	2	2	4	60
O_3	4	3	2	3	60
Required	60	30	50	50	Total 190

up the total requirement for D_2. This still leaves 40 at O_2. Proceeding in this way we get the basic solution in Table 9—notice that it *is* a basic solution. The south-east rule will always yield an initial basic solution.

The next step is to determine the cost differences for the unused origin-destination pairs. The method for doing this is the heart of the transportation algorithm. Let us consider the (O_2, D_1) box. We construct the following closed path:

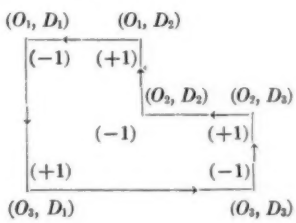


Except for the initial corner at (O_2, D_1), each corner of the path corresponds to a basic activity in the given solution; beginning with $+1$ at the initial corner, successive corners are assigned -1 and $+1$ until the initial corner is reached. These ± 1's are the counterparts of the column entries in the body of the simplex tableau. The cost difference for (O_2, D_1) is obtained by multiplication of ± 1 by the corresponding unit costs c_{ij} and adding:

$$(+1)c_{2,1}+(-1)c_{2,2}+(+1)c_{1,2}+(-1)c_{1,1}=3-2+3-2=2.$$

Thus, 2 appears as the cost difference for (O_2, D_1) in Table 9). (The smaller numbers in the upper right-hand corners are the given unit shipping costs, carried along for ease of calculation.)

Next, consider the (O_3, D_1) box. For this we have the following configuration;



The cost difference is

$$c_{3,1}-c_{3,3}+c_{2,3}-c_{2,2}+c_{1,2}-c_{1,1}=4-2+2-2+3-2=3.$$

The procedure for determining cost differences is, in general the following. Beginning with the box to be evaluated, construct a closed path consisting of successively horizontal and vertical line-segments each of whose corners (aside from the initial corner) lies at a basic activity; assign alternatively ± 1 to the corners. Determine the cost difference by multiplication into the unit shipping costs and adding. Applying this method to Table 9, yields the entries shown. Observe that the present tabular technique, exemplified by Table 9, is quite different from simplex tableau.

We now change the basic solution by introducing the activity $x_{1,4}$, in other words, shipment from O_1 to D_4—this decision is dictated by the appearance of the largest negative cost difference from that activity in Table 9. This cost difference of -3 says that each unit of $x_{1,4}$ will result in a saving of 3 in shipping cost. Let y equal the

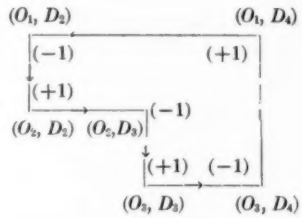
TABLE 9

Initial Basic Solution Amounts Shipped (encircled) and Cost Differences

	D_1	D_2	D_3	D_4
O_1	2 ⑥⓪	3 ⑩	2 −1	1 −3
O_2	3 +2	2 ②⓪	2 ④⓪	4 +1
O_3	4 +3	3 +1	2 ⑩	3 ⑤⓪

Total Cost = 440

activity of the new activity. To determine what the value of y should be, we reconsider the path for the box (O_1, D_4):



Putting

$$x_{1,4} = y$$

means that we must put

$$x_{1,2} = 10 - y, \qquad x_{2,2} = 20 + y, \qquad x_{2,3} = 40 - y,$$
$$x_{3,3} = 10 + y, \qquad x_{3,4} = 50 - y.$$

Hence the largest possible value of y is

$$y = 10.$$

In this way, the activity $x_{1,2}$ is dropped out of the basis in favor of $x_{1,4}$; the new basic solution appears in Table 10.

The entire procedure is now iterated to produce Table 11. In this simple problem, the iteration terminates with an optimal solution at this stage; the solution is optimal because all the cost differences are nonnegative. The

TABLE 10

Second Basic Solution

	D_1	D_2	D_3	D_4
O_1	2 ⑳	3 +3	2 +2	1 ⑩
O_2	3 −1	2 ㉚	2 ㉚	4 +1
O_3	4 0	3 +1	2 ㉚	3 ⑩

Total Cost = 410

steps which have been outlined for the illustration, however, show how to solve any transportation problem as expressed in the general form Eq. 7., Eq. 8. and Eq. 9.

Several additional remarks are in order. If we inspect Table 11, we find , for example, a zero cost difference for (O_3, D_1). What would happen if we introduced this activity into the basis? We would expect to obtain an alternative optimal basic solution, and indeed, if we proceed with the algorithm an additional step, we do obtain another optimal solution, as shown in Table 12. Thus, we see that a transportation problem, or more generally, a linear programming problem, can turn out to have more than one optimal solution. The following general remarks can be made concerning the *number* of optimal solutions of a linear programming problem. If there is only one optimal solution, then it is a *basic* optimal solution. If there is more than one optimal solution then there is a certain finite set of *basic* optimal solutions, and *every* optimal solution is a combination of the basic ones. "Combination" is to be understood in the sense of a linear combination with nonnegative coefficients adding up to 1. For example, the optimal basic solution of Table 11 may be written as

$$X = (30, 0, 0, 40, 30, 30, 0, 0, 0, 0, 50, 10),$$

ordering the activity levels in a prescribed manner. Using the same ordering, the optimal basic solution of Table 12

TABLE 11

Optimal Basic Solution

	D_1	D_2	D_3	D_4
O_1	2 ㉚	3 +2	2 +2	1 ⑩
O_2	3 ㉚	2 ㉚	2 +1	4 +2
O_3	4 0	3 0	2 ㊿	3 ⑩

Total Cost = 380

may be written as

$$Y = (20, 0, 0, 50, 30, 30, 0, 0, 10, 0, 50, 0).$$

Then

$$Z = pX + qY, \qquad p + q = 1, \qquad p \geq 0, q \geq 0$$

will always be an optimal solution, also, For example, with $p = q = \frac{1}{2}$,

$$Z = (25, 0, 0, 45, 30, 30, 0, 0, 5, 0, 50, 5)$$

is another (nonbasic) optimal solution. Similarly, with $p = 9/10$, $q = 1/10$, we obtain an optimal solution

$$Z = (29, 0, 0, 41, 30, 30, 0, 0, 1, 0, 50, 9).$$

The basic optimal solutions are the building blocks for all optimal solutions.

In a particular transportation problem, we may wish to exclude certain shipping routes entirely—this is easily done by applying the foregoing algorithm with the proviso that at no stage do we introduce one of the excluded activities into the basis. What this amounts to is assigning

TABLE 12

Another Optimal Basic Solution

	D_1	D_2	D_3	D_4
O_1	⑳	+2	+2	㉚
O_2	㉚	㉚	+1	+2
O_3	⑩	0	㊿	0

Total Cost = 380

a prohibitively large unit shipping cost to the excluded routes, thereby making their cost differences always come out positive.

It is sometimes possible to cast the problem into the transportation model form even if it is not initially of that type. To illustrate this point, we may consider a modification of the example of Table 7. Let us suppose that production level of F_1 is permitted to go as high as 90, and the production level of F_2 as high as 70. The requirements at the warehouses are kept as before. Since the combined production now exceeds the total requirements, part of the problem is to determine at what level to operate F_1 and F_2. That is, in place of equalities for the first two conditions of Eq. 6., we have the inequalities

$$x + y + z \leq 90$$
$$u + v + w \leq 70.$$

The other conditions remain unchanged. This problem can be changed to a transportation type by introducing

a fictitious warehouse, W_4, and interpreting shipment to this warehouse to mean no production—of course, the unit shipping costs to W_4 are taken as zero. The modified model appears in Table 13, and is solvable as a transportation problem. This procedure amounts to introducing slack variables r and s (unused production at F_1 and F_2, respectively) to convert the above inequalities to equations:

$$x + y + z + r = 90$$
$$u + v + w + s = 70$$

with the additional condition

$$r + s = 20.$$

In this form, with eight variables, it falls into the general transportation type Eq. 7. and Eq. 8.

TABLE 13

Transportation Model with Fictitious Warehouse W_4 Representing Unused Production

	W_1	W_2	W_3	W_4	
F_1	2	2	4	0	90
F_2	3	2	1	0	70
Requirement	60	30	50	20	Total 160

SETTING UP A LINEAR PROGRAMMING MODEL

In order to illustrate how a linear programming model may arise in applications, we shall consider a problem that deals with the determination of shipping schedules for a job shop (1). Our concern will be mainly with setting up the model, not computing solutions.

The problem is concerned with the use of productive capacity; to be definite we shall deal with the capacity of a given class of machine tools with common capabilities. We suppose that a certain amount of this capacity has already been committed to production plans, and that this commitment is expressed in terms of a known amount of capacity for each of the succeeding unit time periods in the future. The remaining available capacity is then expressed as a sequence of values

$$G_1, G_2, \cdots,$$

where G_i is the available capacity in the forthcoming ith period. The values G_i depend upon the time i, in general; they may be increasing with i (if committed capacity falls off steadily with time) or they may fluctuate with i.

The problem to be considered is the determination of a shipping schedule for a given end product which can be supported by the available capacity.

In order to formulate this problem more precisely, we must make certain assumptions regarding the job-shop manufacturing process. The end product is a final assembly of an indentured list of parts (subassemblies and detailed parts) which must be manufactured and assembled in a prescribed logical sequence. We suppose a system of set-back times prior to shipping exists for assigning a point in time when each manufacturing operation is to be carried out on each part. We also assume that the lot size for a part is the number of those parts necessary to fulfill the shipping requirement for a single (unit) period. These two assumptions, together with a set of operating standards for the end product in question, enables us to prescribe the *standard work profile* for unit product relative to any particular machine class (or any particular capacity type). This is represented as a set of capacity requirements the periods preceding the shipping period:

$$M_1, M_2, \cdots, M_n.$$

Each M_j is a sum of the machine times for the various operations occurring in the same time period and relating to the indentured parts for the given unit product. The meaning of the profile is this: in order to ship a unit end product in any given period, it is necessary to use M_n of the capacity under consideration in the first preceding period, M_{n-1} in the second preceding period, $\cdots$, M_1 in the nth preceding period.

We are now in a position to write down the feasibility conditions for a shipping schedule. In order to simplify notation we shall suppose that the standard work profile stretches over only three periods.

$$M_1, M_2, M_3.$$

(The modification is easily made for the general case.) We let x_1 denote the amount to be shipped in the earliest possible period—this is actually four periods from the present because of the set-back of three in the standard work profile. Then $x_2, x_3, \cdots$, are the amounts to be shipped in the succeeding periods. Each (nonnegative) x_i is an activity level; the unit activity for x_1, for example, is represented by the column vector

$$P_1 = \begin{pmatrix} M_1 \\ M_2 \\ M_3 \\ 0 \\ 0 \\ 0 \\ \vdots \end{pmatrix},$$

each row giving capacity requirement for a single period. Unit activities for successive activities are

$$P_2 = \begin{pmatrix} 0 \\ M_1 \\ M_2 \\ M_3 \\ 0 \\ 0 \\ \vdots \end{pmatrix}, \qquad P_3 = \begin{pmatrix} 0 \\ 0 \\ M_1 \\ M_2 \\ M_3 \\ 0 \\ \vdots \end{pmatrix}, \cdots.$$

To obtain the total capacity consumed in each period, we multiply the activity level x_i into each P_i and take the sum. Using the fact that G_k is the capacity available in the kth period (from the present) we obtain the linear restraints

$$x_1P_1 + x_2P_2 + \cdots \leq \begin{pmatrix} G_1 \\ G_2 \\ \cdot \\ \cdot \\ G_k \\ \cdot \\ \cdot \\ \cdot \end{pmatrix}.$$

Written out, this is a chain of inequalities

$$\begin{aligned} M_1x_1 &\leq G_1 \\ M_2x_1 + M_1x_2 &\leq G_2 \\ M_3x_1 + M_2x_2 + M_1x_3 &\leq G_3 \\ M_3x_2 + M_2x_3 + M_1x_4 &\leq G_4 \\ M_3x_3 + M_2x_4 + M_1x_5 &\leq G_5 \quad \text{Eq. 10.} \\ \cdots\cdots\cdots\cdots & \end{aligned}$$

In order to terminate this chain, we may assume that the available capacity levels off to the maximum capacity G^* eventually, i.e.,

$$G_{K+1} = G_{K+2} = \cdots = G^*.$$

With this, we suppose that x_i levels off to the steady value

$$x^* = G^*/(M_1 + M_2 + M_3)$$

beginning with x_{K+1} (that is, three periods later). Hence Eq. 10. ends as

$$\begin{aligned} M_3x_{K-2} + M_2x_{K-1} + M_1x_K &\leq G_K \\ M_3x_{K-1} + M_2x_K &\leq G^* - M_1x^* \\ M_3x_K &\leq G^* - (M_1+M_2)x^*. \quad \text{Eq. 11.} \end{aligned}$$

Conditions of Eq. 10. and Eq. 11. then, together with

$$x_i \geq 0 \qquad (i = 1, 2, \cdots, K)$$

are the conditions for a shipping schedule $(x_1, x_2, \cdots, x_K)$ to be *feasible*.

It is natural to assume as a criterion of optimality that the total production

$$\sum_{i=1}^{K} x_i = \text{maximum}.$$

This particular objective function turns out to have certain disadvantages in this problem. For example, it may be desirable to have the optimal x_i increasing with i when the G_i are increasing with i, but the criterion above does not always lead to increasing x_i when the G_i are increasing. Therefore, we may wish to adjoin additional conditions to Eq. 10. and Eq. 11., namely,

$$x_1 \leq x_2 \leq x_3 \leq \cdots \leq x_K,$$

which is really $K-1$ more inequalities.

We shall carry this example no further. In the paper referred to, in which this problem is studied in detail, the emphasis is on simple methods of obtaining workable feasible schedules without entering upon calculations as detailed as the simplex algorithm. These methods are built upon the special nature of the feasibility conditions Eq. 10.

SHADOW PRICES—THE DUAL PROBLEM

To illustrate the concept of a "shadow" (or "imputed") price, let us reconsider the example

$$55x_1 + 50x_2 + 45x_3 = \text{maximum}$$

with nonnegative x_1, x_2, x_3 subject to

$$\begin{aligned} 5x_1 + 2x_2 + 3x_3 &\leq 105 \\ 3x_1 + 5x_2 + 2x_3 &\leq 65 \\ x_1 + 3x_2 + 4x_3 &\leq 115. \quad \text{Eq. 12.} \end{aligned}$$

With the given amounts of capacity available, namely, 105 units of machine class 1, 65 of machine class 2, and 115 of machine class 3, we have seen that by operating optimally we may realize a profit of 1425. We now raise the question: what is the value of an additional unit of capacity of machine class 1? Taking for granted that we can always operate optimally, the answer is: the difference between the maximum profit when 105 is replaced by 106 in Eq. 12., and the original profit 1425. Now it is easy to see that the maximum profit remains at 1425 when we change from 105 to 106 in Eq. 12. This may be verified, for example, by noting that in Table 6 if the activity level of P_4 is changed from 6 to 7, then the feasibility conditions are met but the rest of the table is unchanged. In particular, the profit difference row remains nonnegative, so that we still have an optimal profit of 1425. Hence, the *shadow price of a unit of machine class* 1 *is* 0. This could readily be guessed—the optimal solution did not use the full capacity of class 1 even at the original level 105; so an additional unit of this capacity cannot help us operate at a higher profit level.

The story is different for class 2. If we increase the capacity from 65 to 66, we find an optimal solution of $x_1=3.4$, $x_3=27.9$, $x_4=4.3$. The maximum profit increases from 1425 to 1442.5; hence, *the shadow price of a unit of class* 2 *capacity is* 17.5. For class 3, by a similar approach, we find a shadow price of 2.5.

These shadow prices are frequently of greater significance in the analysis of a linear programming application, and may be more pertinent than the optimal solution itself. In the simple illustration above it would guide us in determining whether or not to increase the capacity of class 2. If the market price of additional capacity is less (more) than the shadow price 17.5, then it would be advisable (inadvisable) to expand capacity.

Consider a general linear programming problem in the following form:

$$\text{maximize } F(x_1, x_2, \cdots, x_n) \qquad \text{Eq. 13.}$$

where

$$F(x_1, x_2, \cdots, x_n) = c_1x_1 + c_2x_2 + \cdots + c_nx_n,$$

with $x_i \geq 0$ subject to

$$\begin{aligned} a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n &\leq b_1 \\ a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n &\leq b_2 \\ \cdots\cdots\cdots\cdots\cdots\cdots & \\ a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n &\leq b_m. \end{aligned} \qquad \text{Eq. 14.}$$

We may refer to the $b_1, b_2, \cdots$ as "resources." At given resource levels, the shadow price of a particular resource b_i is the change in the maximum of F for unit change in b_i. In general, the shadow price of a resource will depend upon the particular level of all the resources.

It would appear that to determine the shadow price of a given resource, it is necessary to solve another linear programming problem, one in which that resource is slightly increased. Thus, it might be necessary to solve as many problems as there are resources. Fortunately, this need not be done. There is a very direct connection between the shadow prices and the simplex algorithm, and it is this: *the entries under the slack activity vectors in the last (difference) row of the optimal tableau give the shadow prices.* Thus, in the last row of Table 6 we find the entries 0, 17.5 and 2.5 for the slack activities relative to class 1, 2 and 3, respectively. These are precisely the shadow prices we determined above.

The concept of the shadow price is intimately connected with the so-called *dual problem* to problem Eq. 13. and Eq. 14. By interchanging "max" and "min", the b's and c's, $\leq$ and $\geq$, and the columns and rows of the a_{ij}, we can formulate the dual problem:

$$\text{minimize } G(y_1, y_2, \cdots, y_m) \qquad \text{Eq. 15.}$$

where

$$G(y_1, y_2, \cdots, y_m) = b_1y_1 + b_2y_2 + \cdots + b_my_m$$

with $y_i \geq 0$ subject to

$$\begin{aligned} a_{11}y_1 + a_{21}y_2 + \cdots + a_{m1}y_m &\geq c_1 \\ a_{12}y_1 + a_{22}y_2 + \cdots + a_{m2}y_m &\geq c_2 \\ \cdots\cdots\cdots\cdots\cdots\cdots & \\ a_{1n}y_1 + a_{2n}y_2 + \cdots + a_{mn}y_m &\geq c_n. \end{aligned} \qquad \text{Eq. 16.}$$

The *duality theorem* of linear programming asserts that the optimal values of the two problems are the same, i.e.,

$$\max F = \min G.$$

Furthermore, the optimal y's for the dual problem are the shadow prices for the original problem (similarly, the optimal x's are the shadow prices for the dual problem). This remark and the earlier remark that the optimal simplex tableau yields the shadow prices, shows us that when we solve the original problem by the simplex method we are at the same time solving the dual problem. The problem dual to Eq. 2., Eq. 3. is

$$\text{minimize } 105y_1 + 65y_2 + 115y_3 \qquad \text{Eq. 17.}$$

for nonnegative y_j satisfying

$$\begin{aligned} 5y_1 + 3y_2 + y_3 &\geq 55 \\ 2y_1 + 5y_2 + 3y_3 &\geq 50 \\ 3y_1 + 2y_2 + 4y_3 &\geq 45 \end{aligned} \qquad \text{Eq. 18.}$$

The optimal solution, according to Table 6, is

$$y_1 = 0, \qquad y_2 = 17.5, \qquad y_3 = 2.5. \qquad \text{Eq. 19.}$$

It is readily calculated that the value of the objective function of Eq. 17. is, in fact, 1425—the optimal value for the original problem.

When solving a linear programming problem in a practical situation, it is sometimes preferable to solve instead the dual problem because it is computationally simpler to do so. It is an easy matter to derive from this the optimal solution of the original problem. We have seen how to do this when the simplex method with slack variables is used as the technique of solution. However, there are two connections between a problem and its dual which are useful in making the transition between optimal solutions of a primal problem Eq. 13., Eq. 14. and its dual Eq. 15., Eq. 16. without regard for the particular technique of solution. They are: (*a*) if an optimal solution of Eq. 13. satisfies any one of the m relations Eq. 14. say the jth relation, as a *strict inequality*, then the corresponding dual variable y_j has the value *zero* for an optimal solution of the dual problem; (*b*) if an optimal solution of Eq. 13. has one of its n variables, say x_i, *strictly positive*, then the corresponding dual relation—the ith relation in Eq. 16.—is satisfied as an equality for an optimal solution of the dual problem. Let us apply these results to the earlier example Eq. 2. and Eq. 3. Recall that in the optimal solution, the first relation of Eq. 2. resulted in a strict inequality; consequently, for an optimal solution of Eq. 17. we must have $y_1 = 0$. Furthermore, since $x_1 = 3 > 0$ and $x_3 = 28 > 0$ we must have the first and third relations of Eq. 18. satisfied as equations. Thus,

$$\begin{aligned} 3y_2 + y_3 &= 55 \\ 2y_2 + 4y_3 &= 45. \end{aligned}$$

Solving these equations leads to the previous solution Eq. 19.

Let us view the linear programming problem Eq. 13., Eq. 14. as one which depends upon the $m+n$ parameters $b_1, b_2, \cdots, b_m, c_1, c_2, \cdots, c_n$. The dependence of the maximum value of F may be made explicit by using $F^*(b, c)$ to denote this optimal value:

$$F^*(b, c) = \max F.$$

Similarly, we may use

$$x_i^*(b, c)$$

to denote an optimal solution for a given set of values of the parameters. (Here b and c are used to stand for sets

of m and n numbers b_j and c_i, respectively.) The shadow price with respect to b_j, that we have already discussed, is the (partial) derivative of F^* with respect to b_j. Let us explore further this dependence upon b.

If we hold all parameters b, c fixed except a particular one, b_j, then it can be argued that F^* is a *piecewise linear function* of b_j, that is, its graph is a broken line as a function of b_j. Consider a particular value b_j^0. Corresponding to b_j^0, there will be a certain optimal basis; in the last row of the simplex tableau the differences will all be nonnegative, indicating optimality. Now, suppose we start increasing b_j^0. The difference row in the tableau is independent of the parameters b—it depends only on c and the coefficients a—and the optimality condition, as far as nonnegativity of the difference row is concerned, remains valid for the basis already at hand. As long as the feasibility equations can be satisfied with the increased value of b_j, holding at 0 all x_i outside the given basis, then the optimal basis does not change (of course, the activity levels, that is, the values of x_i, change for the activities in the basis). There will finally come a point, for a sufficient increase in b_j, when the feasibility conditions cannot be met with the given basis, and then the optimal basis must be changed. In the interval of values of b_j where the basis remains fixed, the optimal x_i^* are *linear functions* of b_j—this is so because they are solutions of m equations in m unknowns with the parameters b on the right side of the equations. The function F^* is also linear in b_j for the same interval, since $F^* = \sum c_i x_i^*$. Thus, we see that F^* and x_i^* are piecewise linear functions of any particular parameter b_j, and that the breaks in the linear portions occur where the basis for an optimal solution is changed.

The dependence of F^* and x_i^* on any particular parameter c_i can also be analyzed. Again, if we begin with a particular value c_k^0 we shall have an optimal basis and a row of nonnegative differences in the optimal tableau. If c_k^0 is now increased, it is these differences that must be examined, rather than the feasibility equations—in fact, the feasibility conditions are not related to c, and changing c_k^0 leaves both the optimal basis and its activity levels x_i unchanged; that is, the x_i^* remain constant, independently of c_k. On the other hand, as c_k changes the differences will change, and eventually a sufficient increase in c_k^0 will result in the appearance of a negative difference in the final row of the tableau—this means that a shift in basis is required to obtain an optimal solution. In the interval of values of c_k for which the given basis remains optimal, x_i^* remains constant and $F^* = \sum c_i x_i^*$ is a linear function of c_k. Thus we see that F^* is a piecewise linear function of c_k, with the breaks in the graph occurring when a change in optimal basis is required. It should be noted that the x_i^*, however, are step functions of c_k, that is, discontinuous graphs made up of horizontal line segments.

Without going into details, the following general statements can be made regarding the dependence of the solution of a linear programming problem on the "resources" b_j and the "cost" coefficients c_i. The optimal value $F^*(b, c)$ is *bilinear* in the variables b, c, i.e.,

$$F^*(b, c) = \sum_{i,j} c_i f_{ij} b_j. \qquad \text{Eq. 20.}$$

Regarded as a function of b, it is linear,

$$F^* = \sum_j \left(\sum_i c_i f_{ij} \right) b_j$$

and the coefficients of b_j are the "shadow prices" of F^* with respect to b_j—thus these coefficients are the solutions of the dual problem. Regarded as a function of c, it is also linear,

$$F^* = \sum_i \left(\sum_j f_{ij} b_j \right) c_i$$

and the coefficients of c_i are the optimal values of x_i. The particular expression Eq. 20. with a fixed matrix of coefficients f_{ij} holds only for a certain range of values of b_j and c_i; in other ranges, the same type of formula holds, but the matrix of coefficients f_{ij} must be changed.

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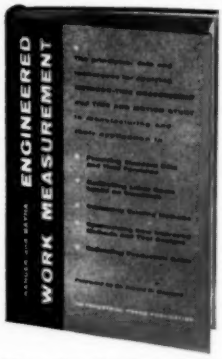

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Some Economic Aspects of the Cold War

by **NEIL H. JACOBY**

Dean, Graduate School of Business, University of California, Los Angeles

DURING the last few years I have had the honor and duty of representing our country abroad in a number of economic missions, in Paris, London, Rome, and New Delhi. Last year for the first time I came into official contact with representatives of the USSR when serving in Geneva as US representative in the Economic and Social Council of the United Nations. You may be interested in some of my reactions to the men in the Soviet delegation, with whom I had to deal over a period of some six weeks and who entertained me and whom I entertained on several occasions. I found these Soviet representatives highly trained in economic matters. The Soviet Union doesn't send retired politicians or untrained people to represent it. Mr. Alexei Zakharov, who headed the USSR delegation at Geneva, was one of seven deputy foreign ministers of the Soviet Union, a professional diplomat and a well-trained economist. I found the members of the Soviet delegation confident, even cocky, in their attitude. They knew then how far ahead they were in military technology. This was before Sputnik. I didn't know it at that time, but I could see that they had no fear of our military power and that they felt quite confident about their own military power.

I found the Soviet delegation stressing economic matters. They spoke a lot about "competitive co-existence," a phrase to which we drank many toasts in both Vodka and Scotch. Their line was that nuclear weapons and military warfare were an abomination, that their economic system is more productive than ours, and they were willing to compete with us economically, and to let time judge the results. I think they honestly believed this. The Soviet delegation was prepared with a great many proposals and resolutions which they brought before the ECOSOC meeting in Geneva. They suggested that we ought to have a world economic conference of nations. They suggested a world conference of academic economists. They supported a United Nations loan fund to help the economically backward countries. To all of these proposals I had been instructed by my Government to say "No."

Now, of course, many of these Soviet proposals were put forth for propagandistic purposes. Some of them were "phonies." Yet I confess that I did not feel very comfortable when Mr. Zakharov cornered me at a diplomatic reception and said: "My country has put forth proposals for world economic progress. Where are the proposals of your country?" I found the representatives of the 18 nations whose members sit in the Economic and Social Council of the United Nations, many of them basically friendly to our country, looking anxiously to the United States to take the initiative. What proposals do we have?

I have pondered this personal experience at Geneva. It has convinced me of the truth of something I had suspected for some time from my studies and research, namely; that the "cold war" will be fought on the economic front, and the opening battle has already begun. It convinced me that the American people must come to understand that this economic conflict with the Soviet Union is a conflict "for keeps." It must be fought by us with the same sense of urgency and the same dedication that Americans have shown in the past—after the Lusitania was sunk, or after Pearl Harbor.

COMPETITIVE CO-EXISTENCE

After all, why should the leaders of the Soviet Union not speak of competitive co-existence? Wouldn't the Kremlin be foolish to provoke a shooting war as long as they believe there is a good chance of achieving their aim of world domination by economic and cultural penetration? For, believe me, world domination is their aim. We should make no mistake about that. Soviet society is a power society. It can be maintained only by acquiring more and more power. The Soviet Union sees in the United States the citadel of Democratic capitalism. It sees in our society, and in our economy, the antithesis to its own system of totalitarian socialism. Russia would seek to destroy us by military force, if it believed this possible, without itself suffering mortal wounds. But in view of our currently great deterrent military strength, it will seek instead to dominate the United States by making us, if it can, an ever-smaller island of freedom within a growing sea of Communist power. It will seek to bind to itself an increasing number of the neutral and uncommitted nations of the world by economic assistance and by trade, leading those countries that trade with it into economic dependence. Ultimately, it will hope to achieve their cultural penetration, and finally their satellization. We saw this process occur in East Germany and in Hungary.

SOVIET ECONOMIC AIM

What is the primary Soviet economic aim? I think that we can take at face value the economic goal of the Soviet Union that was expressed at the 20th Congress of the Communist Party very recently: "Through peaceful competition and in an historically short period of time to overtake and surpass the most highly capitalist countries in per capita output." The Soviet Premier, Nikita Khrushchev, has put Soviet aims in even more decisive,

and flamboyant, language when he said: "We will bury you. Watch out, we are stepping on your tail." One of the remarkable facts of very recent times is that the Soviet Union has emerged as an important factor in world trade, and it has launched far-reaching programs of economic development aid and technical assistance to the underdeveloped nations of Asia and Africa. So far as we can tell, these Soviet foreign aid programs are now involving something of the order of half to three-quarters of a billion dollars a year.

SOVIET ECONOMIC GROWTH POTENTIAL

You may very well ask: "Do the facts about Soviet economic growth cause us to take the boasts of Khrushchev and the Communist Party seriously?" I think that, when we look at the facts, the answer is a rather sober, "yes." While reliable economic statistics, comparable to United States figures on our gross and our net national production, are lacking for the Soviet Union, all of the expert studies on Soviet economic growth converge on the conclusion that since the second World War, the real Soviet gross national production has been growing at a rate of about seven percent a year. This is a rate approximately twice the rate of growth in the real output of the US economy since World War II.

The high Soviet growth rate in recent years has been brought about by several factors. In the first place, there has been a very rapid increase in the labor force, the number of people at work on Soviet farms and in factories. The annual increase has ranged between one and two million persons, which is about double the annual gain in the US working force. In the second place, there has been in the Soviet Union a very high rate of growth in investment and capital accumulation. This has been achieved by holding down the consumption of the people, who continue today to lack comfortable housing and the kind of clothing and food and transportation that the people of a Western economy as productive as that of the Soviet Union would normally expect to have. In the third place, there has been in the Soviet Union a very high rate of expenditure on research and development and on scientific education and technical training. These outlays have paid off in an extraordinary increase in the annual gain in productivity, that is, in the output per man-hour.

As a result of a single-minded drive to build up heavy industry, which, of course, supports an immense war machine, the Soviet Union is now producing about fifty-two million tons of steel a year. Our steel capacity is more than double this amount, but this is about as much steel as we're actually producing at the present time of recession. The Soviet Union is now producing about eighty per cent as much coal as we produce. The most recent figures indicate that it is producing more machine tools than we are currently producing. These figures alone are highly misleading, because the output of consumer goods, of cars and refrigerators and home appliances and all of the services and goods that consumers use in our country, is in the Soviet Union microscopic compared to ours. But if we average the goods in the production of which they're moving up rapidly with those in which they're backward, the *aggregate real product* of the Soviet economy today is probably between thirty-five and forty per cent of that of the United States economy operating at capacity.

This is a very impressive achievement, considering the fact that it is only about 30 years since Stalin first consolidated his internal power in 1928, and launched the first Five-Year Plan under forced draft. This gain in output was brought about, as we know, by ruthless suppression of personal freedom, and by the starvation of millions of peasants, who were forced to deliver their farm products to the State in order to supply the industrial workers with food in this period of forced industrialization.

A COMPARISON BETWEEN ECONOMIES

Will the output of the Soviet economy continue to grow at this fantastically high rate of seven per cent per annum? I think there are several reasons for believing that the future growth rate will be somewhat less than it has been in the past. In the first place, beginning now and continuing until the late 1960's, the Soviet population of working age will grow relatively little, if at all. The reason for this is that we are now coming into the period in which the babies born during World War II and immediately thereafter will be reaching working age. We know that the Soviet birth-rate in those years was very low, and that the infant mortality was very high. Of course, our own country will suffer the same kind of disability, but in much less degree than the Soviet Union, which bore the full brunt of the German attack.

A second point is that the Soviet Government will find it necessary, indeed, it is already finding it necessary, to increase relatively the production of consumer goods, including housing. This will reduce its very high rate of investment and capital goods production in the future. The Russian people are demanding better living conditions.

Finally, as the Soviets use up the opportunity to increase their productivity by drawing upon the superior western methods and knowledge, which they have been able to utilize heretofore, they will be forced to find technical improvements of their own. The rise in productivity will not be as great as in the future.

I think this is a rather important point. Has it occurred to you that the Soviet economic objective is a very simple one to formulate—to catch up with the United States. But what is our economic objective? We have nobody to catch up to! We have the task of formulating new economic objectives for ourselves. As the Soviet economy moves up, it will, I believe, face real and difficult prob-

lems. As their economy becomes more oriented to the needs of consumers, the planners will come up against these difficult and fundamental problems of what consumers want.

We should not exaggerate Soviet achievements. A number of myths have been fabricated, cultivated, and are being spread in the world which ought to be punctured. One hears it said, for example, that the Soviets have done in forty years what it took 175 years for the United States to do. This is absolutely false. The Soviet economy was about as advanced as United States economy of, let us say, 1875 or 1880 when the Communists seized power in 1917. Now, forty years later, the Soviet economy has achieved about the same over-all stature as the US economy had achieved in 1920. If you really look at the facts, the growth of the Soviet economy under a brutal form of Communism probably hasn't been any greater than the growth of the US economy between 1880 and 1920 under democratic capitalism. We ought to not lose our sense of perspective in viewing the economic achievements of Communism. Nonetheless, we would be foolish not to regard them very seriously.

One of the most important facts for Americans to understand is that, according to the most reliable estimates, the Soviet economy is graduating each year about twice as many scientists and engineers as is the United States. This is most important, because these graduates will support basic research on a much larger scale than will our own country in future years, unless we change our course. We know that developing science and technology lie at the basis of our future economic growth. Just as we have learned, through Sputniks I, II, and III, to know the USSR as a formidable potential military adversary, we should now recognize the Soviet Union as an equally formidable adversary in the global economic conflict. The productive power of the Soviet economy will continue to grow rapidly, in all likelihood, and it will enable the Soviet economy—this is the point I'm coming to—to support a massive program of technical assistance and development loans to other countries that it wishes to bring within its orbit and to satellize.

ADVANTAGES AND DISADVANTAGES

Apart from their rapid economic growth, the Soviets enjoy certain advantages in this economic conflict that we're faced with that we should not overlook. In the first place, the Soviet economy and those of a good many underdeveloped countries of the world are more complementary than is the US economy with those of the underdeveloped countries. Russia needs food and fiber. The US has surpluses of these things to dispose of, as a result of our short-sighted policy of supporting agricultural commodity prices at high levels over many years. As a result, it is often easier for these underdeveloped countries to find a basis for commodity trade with the Soviet Union than it is with the United States.

In the second place, the Soviet Union can and does cut prices in order to foster trade for its political ends. Our foreign trade is conducted, as it should be, by private enterprises who have costs to meet, and who can't cut prices for political purposes. They have to make a profit or at least avoid a loss to their stockholders. This is something that a State-controlled economy need not be concerned about.

Another disadvantage that we face at the present time is that the Soviet Union is able to offer a larger variety of goods suited to underdeveloped countries than is the United States. By and large our equipment is of advanced design, suited to US conditions. Soviet equipment, such as their automotive equipment, trucks, etc., is simpler, more rugged, more easily kept in operation, and better suited to a primitive country.

The fourth Soviet advantage is even more important. The Soviet Union sends its technicians along with its goods. I met many of them in India. They are trained in the language of the country to which they go. They can be drafted for foreign service by their Government. They teach the natives the use of the Soviet equipment. We Americans, by and large, are poor linguists. Economic opportunities are so attractive at home that it's hard to attract able, young Americans abroad. Unlike the Soviet Government, our Government does not draft able young people as technical experts for its foreign service.

We should bear in mind our handicaps as we go into this economic conflict. But, on the other hand, America and the West possess very important advantages over the Soviets. Most nations do not like to barter, which is the form of trade that the Soviet Union with its Socialist system usually insists upon. Most nations prefer to *sell* their goods for hard currency, for money that's convertible into any other currency which they can spend anywhere and for the products that they want. Our system of private enterprise, competition, open markets, and freely convertible currencies is, therefore, one that has a very basic appeal throughout the world. Many nations have seen the course of events in Eastern Germany and in Hungary. They understand that heavy dependence upon Soviet trade leaves them open to a loss of their political independence and to their ultimate satellization. So our proper course of action is to overcome those handicaps that we now possess, and to spread the great moral, political, and economic advantages of freedom of enterprise and freedom of trade throughout the world.

What should we do about it? There is not time here to trace all of the elements of the program of action that the US will have to evolve to win this economic war. Perhaps, I can put forth a few thoughts about the nature of such a program.

AMERICAN ECONOMIC AID

It is absolutely essential that we Americans understand the essentiality of binding more of the nations of the free

world to our own in a mutually profitable network of trading and investing relationships. I dislike the phrase "foreign economic aid." It's a misnomer. What we are talking about is essentially *American* economic aid, because it involves trade and investment that will benefit ourselves as well as the peoples of these other countries. It will foster our own national security and raise our own standards of living. The purpose of our economic assistance to underdeveloped countries is not to "buy" friends. We provide economic assistance because it is in *our* interest that any country in the world is economically and politically strong enough so that it can be independent of *any* foreign domination, including domination by the United States.

The gains that the United States can make from freer trade and investment throughout the Free World, including those underdeveloped countries which include about two-thirds of the Free World's population, go far beyond our national security in a military sense, by which I mean getting US bases abroad or preventing the Soviet Union from gaining foreign bases. The benefits that we can obtain are necessary to our continued economic progress. May I call your attention simply to two facts. First, the United States urgently needs the raw materials of neutral and uncommitted countries throughout this world. We are no longer self-sufficient. We need the oil of the Middle East and the Caribbean. We need the copper, lead, tin, and rubber of the Malayan Peninsula and of Latin America. We need the nickel, bauxite, iron ore, and pulp of Canada and Brazil. Looking to the future, we know that the great undiscovered raw materials of the world lie in these neutral and undeveloped countries of Asia and Africa. Can we allow them to go behind the Soviet Iron Curtain?

Secondly, the underdeveloped countries offer huge potential markets for American products. As we become a more highly industrialized society, we shall need larger foreign markets for the products of our industry in order to pay for the rising volume of raw materials that we import from abroad. We cannot permit these markets to go under Soviet domination.

RECOMMENDATIONS

I can only sketch here the main elements of the kind of bold, but sound, program that we shall have to work out to win the economic cold war.

First, we need progressive removal of restrictions on trade, whether they are tariffs or quotas or any other restriction. The other countries of the world have repeatedly told us, and they mean it, "We want trade, not aid." The renewal of the Reciprocal Trade Agreements Act by Congress was one of the most hopeful and inspiring events of recent times.

Second, we need to encourage American businesses to invest more abroad, by giving tax advantages and by other measures that can be devised.

Third, we need to persuade other countries to improve the climate for American investment, by the adoption of proper investment codes which assure fair treatment of the property of foreign investors, of their employees, and of their profits. This is a subject on which we ought to be working more assiduously than we now are.

Fourth, we must launch larger technical assistance programs to help other countries learn how to use capital more efficiently and thereby improve their productivity. This may ultimately require a new kind of foreign service, with better salaries and stronger inducements to capable and dedicated people to enter it.

Fifth, I suggest that we ought to enlarge our own United States Development Loan Fund which was set up at the last session of Congress, and which finances non-bankable but economically sound development projects in other countries of the world.

Sixth, I believe that we should sponsor an enlargement of the program of the International Bank, a very successful institution which finances bankable development projects throughout the world; and that, concurrently, we should also sponsor the establishment of an Economic Development Agency within the United Nations, to foster economically sound but non-bankable development in the less developed countries.

Now, it will take time to do all of these things. But time is running out. We would be wise to move more rapidly than we have been moving in the past. If we do move rapidly, then I have confidence that we shall be victorious in the economic conflict in which we are now joined with the Soviet Union. The society of free men and free institutions must prevail in the end.

Industrial Engineering Methodology

Simulation of the Firm

by **MARTIN SHUBIK**

Consultant, Operations Research & Synthesis Consulting Service, General Electric Company, New York

WHAT do we mean by simulation of the firm? We mean the construction and operation of models of its processes such as: production, inventory, scheduling and forecasting and, eventually, the construction of models for pricing, advertising and other major decision areas. This also involves the construction of models of its environment, for instance, distribution systems, retail systems and other special features of the market.

One of the most basic problems involved in undertaking simulation work is the development of goals or intentions. Why do we want to indulge in this sort of work?

What sort of payoffs do we expect? What are going to be the rationalizations we use to justify the expenditure that is going to have to be made?

In this sort of work we feel that there are many differing payoffs. To undertake the simulation of a firm, if done with care, will pay for itself in many different ways and at many different periods during the work. Among the goals and the payoffs that we perceive are first, and most important, the top managerial goals. They are to investigate the implications of certain major strategic and economic questions that may arise. For example: What will be the effect of a basic change of the distribution system? What will be the effect of a radical change in technology? What are the possible implications of different inventory and pricing policies?

A next level of payoff, which is also of considerable importance, is the general payoff to all members of a firm. This includes the value of the actual construction of the model and the flow diagrams of the processes in a firm as devices useful by themselves for obtaining an understanding of the structure of the firm.

It is simply amazing, once you start to investigate even on a very general major level the processes of how things are done in a firm, how many gaps and misconceptions and how much folklore are discovered. It is quite incredible to see the divergence between what a process actually looks like and some of the folklore that is within the firm. As an example, from a study done some years ago, I was working on some problems of capacity. As a short cut in our investigation, we asked the top management to define what they meant by capacity, to agree upon a reasonable concept of capacity and to estimate the maximum capacity for a certain base. The second estimate had a rather interesting property. There were about seven or eight people involved. The smallest was about 500% smaller than the largest, and the largest was about 40% smaller than the historical figures we happened to have discovered for the year of 1943.

DECISION PROCESSES

For these reasons we feel the mere putting down in a consistent manner of flow diagrams and logical charts for the decision processes of the firm are of value to the operating personnel. Furthermore, we hope to use the device of simulation as a method for stimulating interest and understanding in the problems of contingent forecasting or anticipation. In other words, it is well known that when somebody asks for a forecast, in that forecast we have to assume a whole set of given or fixed conditions, such as "next year the level of business will be the same as this year's." It is quite obvious that in some cases, the manager asking for the information would like to have some concept of the sensitivity of this forecast to changes in conditions which he has not necessarily specified.

The third level of payoff comes in research. In my estimation, there are two types of payoffs to be expected. One is associated with the actual processes of model building and the running of the simulation. From the point of view of research, this type of procedure provides people interested in the science of management with tools both for the formulation and the testing of hypotheses. It is important to understand that the discipline of model building has this effect: you find out that the problem you were initially talking about was no problem at all; it was just ill-defined. And, when you try to put it down, it turns into a completely different problem, or it may in some cases just happily disappear.

The second area of payoff for research is closely interlinked with some of the work going on in gaming. One of the basic weaknesses, in my estimation, of the present day use of business decision models and gaming models, comes in the construction of the model. It has been claimed that the current business games are based upon general economic considerations. As an economist, I unfortunately know just how weak general economic considerations can be.

As we learn to describe the decision processes of the firm, and to describe the environment of the firm, we become in a better position to construct gaming models which reflect fairly accurately the physical properties of certain specialized markets. Instead of dealing with a general business game in which a few economic maxims may have gone into the construction of the model, and in which possibly a number of the prejudices of the model builders also have been incorporated, we will be in a position to build gaming models which, for instance, reflect the properties of a heavy industry, a light consumer durable market, a major consumer durable market and so forth.

COMPUTER MODELS

The next point that comes up naturally when one thinks about studying the processes of the firm, is: "Why should we use high speed digital computers for the simulation?" I think that the answer for this was supplied during the first world war in the words of old Bill. It is essentially a question of "if you know of a better 'ole, go to it." The number of variables involved in getting a reasonable description of the processes of a business is great. The problems incurred due to the presence of many random variables and the need for flexibility in being able to vary bits and pieces of the final model are just so great that one cannot really hope to go very far by analytical methods. This, of course, does not mean that one does not use analytical methods. In fact, in this sort of problem, one's very job is to make use of every trick of the trade that is available. If analysis could do the work alone, there would be absolutely no need for simulation.

Given that we intend to use, and in fact, we are forced to use digital computer simulation, in tackling some of the problems mentioned, we should take a look at some of the basic features of model building. In order to study

the firm, we need models of the firm and its market environment, we need hypotheses concerning the behavior of different sections of the firm and its environment. We have, at some point, to try to describe dynamics—try to give a type of motivation so that when this model is finally constructed and is put on a machine for simulation, we have fully described a dynamic process. For example, we will want to include in some models, functions which represent retailer inventory values. In some models, we may also wish to include functions which indicate the distribution of time-lags in a pricing system. For instance, if a factory manufacturing an item decides to cut prices at the factory level, how long does it take for those price cuts to be effective at the dealer level? And, furthermore, we would like to know the orders of magnitude of the price cuts to be expected at the dealer level.

In the construction of a simulation, we need three major kinds of work. They are: 1. analysis—the actual attempt to try to squeeze the most out of the manipulation part of our problem without going to large machines; 2. machines techniques—once we have a model, once we have analyzed it as much as we can, there is the straight problem of how do we handle it on a large scale computer without running up fantastically unnecessary costs, which, as most of us know, is very easy to do; 3. actual empirical work on the firm—the organization of the knowledge and understanding that is present among the members of the firm and is certainly the basic concern of individuals such as Industrial Engineers, Operations Research Personnel, Economists and others.

MODEL BUILDING

A maxim for large scale simulation is to do everything analytically if possible. We should take great care to use our machines with the maximum of sophistication and should be in no hurry to get to the machine until we are pretty sure that we know what we're doing. However, especially for a problem such as the simulation of the firm, where we know that the models of the physical processes involved are, at the very best, highly shaky, the dominating feature will be the care we exert in the construction of the model and in the use of the empirical data. This means that to a great extent some of our work is going to be at variance with the ideas and general warnings of strict mathematical statisticians and many straight physical scientists who are primarily concerned with quantities.

To illustrate this, I want to mention three basic problems, which really cannot be treated, initially, very comfortably by straight statistical considerations in model building. They are: 1. the accuracy and the relevance of a model as a description of a physical process; 2. the accuracy of the functional forms that are used in a simulation (For example, we have just noted that in some simulations we will need a functional form representing retailer behavior.); and, 3. the problem of the adaptivity of errors. We have errors everywhere. We have inaccuracies loaded in every part of our model. Do all these errors and inaccuracies add together and invalidate everything? Or, are they sufficiently under control that the results of a simulation will be meaningful?

Each of the three problems mentioned above, if looked at from a strict statistical point of view (I use this probably in a relatively narrow and prerogative sense) would be sufficient, and we would just stop working in this particular area, if we did not know our subject matter. If we know our subject matter, then that, in many ways, should be the prime consideration. The knowledge of our process, aided by whatever statistical tests and other tests that we can dream up and supply, should be the basic criterion which tells us whether or not we are in a position to go ahead. As a matter of fact, once we get a simulation going, the actual running of the model may begin to answer some of these questions, because where we may have portrayed a process by ten or fifteen variables by doing a sensitivity analysis on certain of the functional forms employed, we may discover that whether or not we were terribly accurate in describing the behavior of a small set of retailers does not seem to matter. If our functional form has the right slope and the right order of magnitude, in some cases, this may easily appear to be sufficient.

Some Practical Simulations of Operations

by **JOHN B. LATHROP**

Department Manager, Company Studies, Operations Research Division, Lockheed Aircraft Corporation

and **JOHN E. WALSH**

Research Specialist, Operations Research Division, Lockheed Aircraft Corporation

USE of a simulation technique is seldom desirable for situations where a suitable analytical model can be readily developed and the resulting analytical problem can be solved without great effort. However, where these conditions are not met the simulation approach can be useful. For the air cargo example given in this paper, determination of a suitable analytical model is reasonably easy but solution of the analytical problem is not feasible for nontrivial cases. For the offense-defense case, development of a satisfactory model is difficult and the analytical problem resulting from any such model would require excessive effort for its solution.

AIR CARGO CASE

The commercial air cargo problem is concerned with the transportation of specified amounts of freight from specified shipment origins to specified destinations. The

carrier is a specified type of cargo aircraft, with many such types to be evaluated, and the freight of various densities and subject to delivery time deadlines. The basic problem is to transport cargo from origin to destination within the specified time restrictions and at minimum cost.

There is no difficulty in developing a suitable analytical model for the air cargo problem. A liner programming framework can be used in which the variables consist of all different kinds of basic flights that can occur in the system. Here a basic air cargo flight is identified by the terminal it leaves, its destination, the departure time, the amount of cargo carried and the characteristics of the cargo carried (density, ultimate destinations, deadline times, weight for each of these subdivisions). Unfortunately, an excessive number of variables is required by this linear programming model except for trivial cases. (1).

As an illustration of the huge number of variables required by the linear programming model, consider the following situation: The system consists of only five bases and the total time period considered is only a day. Use of four-hour increments is assumed to be a sufficiently fine subdivision for scheduling departures of cargo aircraft and six-hour increments are assumed to be adequate for representing deadline times for deliveries. The cargo aircraft can carry a maximum payload of 50,000 pounds and units of 10,000 pounds are assumed to furnish an adequate subdivision for the payload. The cargo is assumed to be available in units of 2000 pounds (a great simplification) and only three different densities are assumed to occur for each unit of cargo. For this highly simplified case, it is found that 6.3×10^{18} variables are required for the linear programming model.

Thus, direct solution of the air cargo problem by use of linear programming is not feasible. However, a feasible approximate solution can be obtained on the basis of simulation. This simulation procedure is outlined and discussed in Air Cargo Example section of this paper.

OFFENSE-DEFENSE CASE

The offense-defense situation considered is of a general nature and has application to many types of warfare. However, the special case considered in the simulation example is limited to a bomber attack opposed by an air defense. Explicitly, the problem examined is defense of the United States against large scale bomber attack. A method of evaluating air defense components and organization for their effectiveness against a variety of enemy attacks is necessary if an efficient and economical air defense system is to result.

A desirable property for any Bomber versus Defense situation is the inclusion of suitable allowance for the effects of uncertainty. That is, the numbers and identities of the defense weapons, bombers, targets, etc. destroyed in an attack are variables with probability distributions. Any attempt to treat these quantities as other than probability variables represents a reduction in realism and accuracy for the Bombers versus Defense outcomes obtained. However, development of a suitable analytical probability distribution model for this situation is difficult and solution of the resulting analytical problem for the probability distributions of the outcomes would require a huge amount of effort.

The principal reason for the difficulties in obtaining a feasible analytical solution to a large scale Bomber versus Defense situation is that the problem is of a massive nature. The factors contributing to this massiveness are:

1. The number, types, and locations of weapons and targets.
2. The strategies and tactics available to the offense and to the defense.
3. The effects of geography, time, altitude, velocity, and countermeasures.
4. The effects of possible enemy attacks on defense elements.
5. Complicated interactions among the variables.
6. The many types and large number of separate probability distributions.

To obtain a feasible approximate solution for this Bombers versus Defense problem, a simulation procedure combining the map exercise, mathematical model, and Monte Carlo techniques was used. This simulation procedure was programmed on a fast electronic computer. Each computer run for a fixed problem furnishes a sample value (multivariate) from the joint probability distribution of Bomber versus Defense outcomes. These runs can be repeated to yield a sample of any desired size from the joint distribution of outcomes. Use of this sample, combined with the techniques of mathematical statistics, furnishes a joint estimate of the probability outcomes of interest. This joint estimate can be made as precise as desired by using a sufficiently large sample size.

The simulation procedure used for this offense-defense situation is outlined and discussed in the Bombers versus Defense section of this paper.

AIR CARGO EXAMPLE

The air cargo scheduling example represents part of a continuing study by the Lockheed Aircraft Corporation of commercial air cargo systems. Factors considered include characteristics of the air cargo market, airplane design parameters, cargo handling methods, schedule requirements, costs of operation, initial investment, etc.

For the simulation example considered, the problem is to perform a specified air cargo task with specified equipment at approximately minimum cost. A single type of cargo aircraft from among many alternatives, is used for the system and its characteristics (payload volume, payload weight, speed, etc.) specified. The principal purpose of one phase of the study is to compare types of cargo aircraft on the basis of the system cost for an optimum schedule.

A cycling time of a day is assumed for the airplanes. That is, at the end of the day there must be the same number of cargo aircraft at each terminal, or in flight

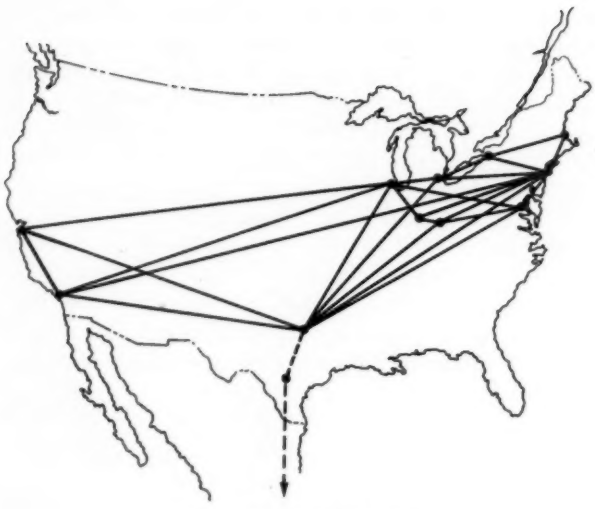

FIG. 1. Air Cargo Network.

between particular pairs of points, as there were at the beginning of the day, although these are not necessarily the same airplanes. There were considerations of the times at which cargo was available for movement and when it was required at its destination, but these are not important to this discussion.

For this illustration we will use a simplified 13-terminal system. The 13-point system furnishes an adequate representation of the cargo situation examined. Figure 1 shows a schematic diagram of the 13-point system and an indication of some of the possible aircraft routes.

The characteristics of the cargo to be transported are given and fixed (i.e., not random variables). Cargo is defined on the basis of origin, destination, delivery deadline, weight, and density.

COST SUBDIVISIONS

The first consideration in developing a simulation procedure was to segregate the system costs into those which are approximately independent of the aircraft schedule (for any reasonable schedule) and those which depend on the schedule. Then, for approximately optimum scheduling, only the costs affected by the schedule need to be considered. These costs can be divided roughly into the three categories: those related to mileage flown, those determined by the number of take-offs and landings, and costs reflecting the number of airplanes required in the system.

Examination showed that, of the costs affected by scheduling, those related to mileage were by far the most important. In fact, the costs associated with the total mileage flown in the system were about five times as great as the costs associated with take-offs, landings and ground operations, and about ten times as great as the investment costs for the aircraft. This is not to say that the number of aircraft required in the system and initial investment in them was unimportant, but that these do not strongly affect costs. With another and equally important measure of effectiveness—return on investment—numbers of aircraft required take on much greater significance.

These relative comparisons indicate that a simulation method for determining the characteristics of an approximately optimum schedule should be satisfactory for cost comparisons if it yields a mileage that is very near the minimum possible (say, within five percent), a number of take-offs and landings that is reasonably near the optimum (say, within 15 percent), and a number of airplanes that is not greatly different from the optimum number (say, within 30 percent). Then the over-all system cost when this schedule is used should not differ very much (say, at most 10 percent) from the cost for an optimum schedule.

A simulation method was developed for determining a schedule with these characteristics. Due to uncertainties in estimation of the cargo market and from other sources, an error of at most 10 percent in total system cost seems to be quite acceptable for the purposes of the study. The "schedule" would be of little use in setting up an airline timetable, but provided a good unbiased basis for comparing airplanes and cargo handling systems.

The accuracy of the model was checked by means of upper and lower bounds to the true values of the total mileage, take-offs and landings, and number of aircraft required. Since the schedule determined by the procedure is feasible, the values for this schedule can be used to determine upper bounds. Lower bounds were determined by considering the geographical setup to be of a strictly linear form based on the direct flight distances for all the combinations of two terminals.

SIMULATION PROCEDURE

The method used to determine an approximately optimum schedule of the type outlined above consists in first converting the geographical locations of the air cargo terminals into a linear ordering and then scheduling airplanes in much the same fashion as trains on a double track railroad with sidings. For the 13-point system, the linear order used is given by Figure 2. For convenience, the terminals are considered as if they lay on an east-west straight line. The linear model is used only for conceptual purposes in selecting a schedule. The resulting mileage, etc., is obtained on the basis of the actual two-dimensional geographical setup.

The first step in the schedule determination consists of constructing an origin-destination table for the cargo to be transported, with amounts of cargo expressed in terms of number of payloads. The next step is to assign direct non-stop flights from origin to destination (Figure 3). These are separated into westbound flights and eastbound flights. Also, the flights are divided into cargo flights and deadhead flights. A deadhead flight carries no cargo, but

is required in order to restore the balance of airplanes in the system.

For westbound cargo flights, the easternmost terminal is considered first. The terminals for which one or more full planeloads of cargo are destined from this terminal receive direct flights. The cargo remaining at the easternmost terminal is then examined for the amounts that go furthest west. Starting from the westernmost terminal and proceeding to the east, the cargo for all such destinations is accumulated until a terminal is reached where the total is at least one planeload. Then as many full planeloads as have accumulated for this terminal and those further west are sent from the easternmost terminal to this terminal. The remaining cargo at the easternmost terminal is then re-examined and the same procedure of proceeding from west to east is followed. Finally, all cargo that remains at the easternmost terminal is flown to the next terminal in the eastwest ordering. Note that only this last cargo transportation can include a flight that does not contain a full planeload.

Having disposed of the cargo for the easternmost terminal, the next step is to consider the resulting cargo situation for the terminal that is the next most eastern in the east-west ordering. Exactly the same procedure is used to dispose of the cargo for this terminal, etc., until all the westbound cargo is disposed of. The same procedure is used to dispose of the eastbound cargo. Finally, the system is balanced (one day cycling period) by using empty flights from those terminals where there are an excess of arrivals to those terminals in which an excess of departures exists. These deadhead flights are routed so as to minimize the number of miles flown in empty flight.

Cargo density enters into determining the effective payload of an airplane and thus the number of payloads, and in the loading and unloading costs associated with take-offs and landings. Deadline times occur in the determination of the minimum number of aircraft needed for the system when this schedule is used. The simulation procedure outlined above is very easy to carry out from a computational viewpoint. In fact, hand computing was found to be feasible for a moderately large number of cases. For a large number of cases, a high speed electronic computer is readily programmed.

In the study, a single machine program combining simulation and evaluation was developed. This machine program has as outputs: airplane mileage, flying hours, ground hours, utilization, load factor, total cost, cost per ton-mile, per cent return on investment, etc.

BOMBERS VS. DEFENSE EXAMPLE

As already mentioned, there are a large number of potentially important factors affecting the interaction of a large scale bomber attack with an air defense system. A simulation approach utilizing map exercises has been found to be useful for evaluating alternatives in complicated situations of this nature. The effects of geography and decision making can be explicitly allowed for. Also, the effects of uncertainty can be introduced directly through the use of appropriate Monte Carlo techniques.

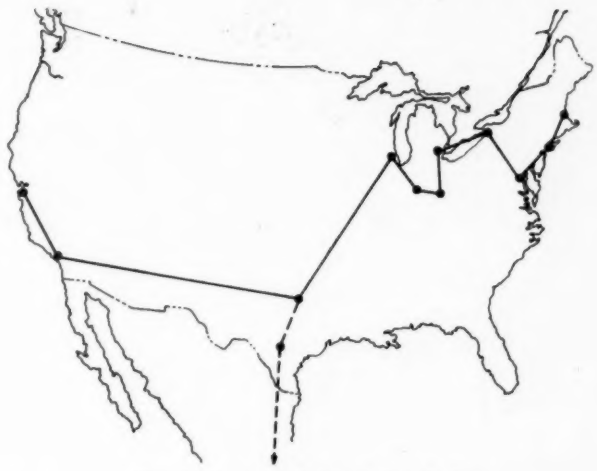

FIG. 2. Linear Ordering of Terminals.

Although satisfactory in principle, it has been found that the working of any non-trivial Bombers versus Defense map exercise is very time-consuming and requires the continued use of high caliber personnel. This is especially true if the map exercise includes Monte Carlo operations. For determination of a map exercise outcome with reasonable effort and a simulation providing for all potentially important factors, a mechanized procedure for Bomber versus Defense map exercises was developed.

THE MODEL

First, mathematical models were derived representing the outcomes of the sequential events of the map exercise. These models relate distance and the probability of detection, distance and decision time, time and the number of weapons dispatched, these with probability of weapon kill, etc. They explicitly allow for the effects of all the factors believed to be important and involve geography, decisions, and Monte Carlo operations regarding offense and defense component performances. A more detailed

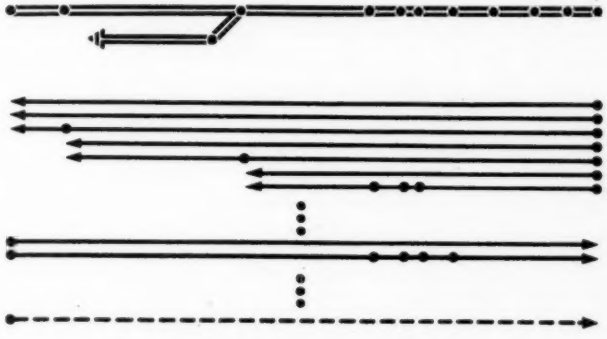

FIG. 3. The Scheduling Procedure.

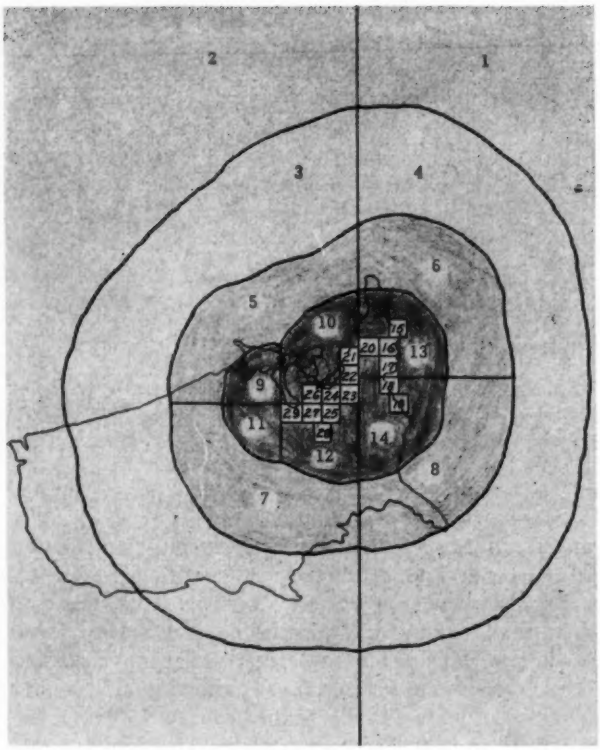

FIG. 4. Typical Sector Subdivision

outline of the factors and effects included is given later. Next, these mathematical models were programmed for an electronic digital computer. The principal contribution of the computer is to perform rapidly the huge amount of bookkeeping and Monte Carlo operations in the simulation as the bomber raid enters the defended area and proceeds to its targets.

The simulation is of a very general nature placing very few restrictions on numbers and types of targets and weapons. A wide variety of both offense and defense decisions and strategies are allowed for. These include attacks on defense weapons and surveillance locations, various counter-measures, great freedom in bomber attack routes and timing, changes in defense strategy on basis of information received about the raid, distant early warning, etc. Both combat and non-combat attrition are included. The targets for the bombers are subject to very few restrictions with respect to the worth, type, and vulnerability.

METHOD OF APPLICATION

The first step in the mechanization of the map exercise consists in constructing a schematic diagram from which the effects of geography are converted into the form used in the mathematical model. This is done by dividing the over-all area considered into contiguous areas called defense sectors. Sometimes sectors are also defined on a time and/or bomber flight altitude basis. Figure 4 furnishes an illustration of a type of defense sector breakdown that might be chosen for the weapons used to defend the Eastern Heartland of the United States.

The defense sectors must satisfy the conditions that their total number is not too large (say, at most 50), that only one type of defense weapon is used in a given sector, and that weapons available for use in a given sector cannot be used in any other sector. Also, the same form of mathematical model must be usable for each sector. At first glance, these conditions might seem to be somewhat restrictive. However, by careful choice of the sectors, little generality is lost because of the conditions imposed.

Given defense sectors satisfying the specified conditions, it is sufficient to give a mathematical model for a general sector. This general sector model depends on time and zero time is defined to be the first time at which a bomber is detected in any one of the sectors. To reduce computation, the state of the activities in a sector is considered only at certain key times, namely the times at which something important could possibly occur.

The bomber paths and timing are put into a form suitable for use in the mathematical model by drawing flight paths on the sectorized map and stating the timing details for each bomber. Even for very large scale raids, each bomber is treated as an individual which may have flight path and timing characteristics different from any other bomber. For each bomber the required data consists of the entering time for each sector encountered, altitude for the sector, its speed, payload, and target assignment.

A randomization process is used to decide which bombers of a group are lost where the group suffers a specified amount of combat or non-combat attrition. The amount of attrition suffered is determined on the basis of a specified probability distribution. For non-combat attrition, this distribution is independent of such things as the size of the bomber group. For combat attrition, this probability distribution depends on the size of the group, countermeasures, etc.

The output of a run of a mechanized map exercise includes the worth of the targets destroyed by the bombers (subdivided by types and location if desired), the number of defense weapons lost (subdivided according to type, location, and time of loss, if desired), and the attrition suffered by the bombers.

This Bomber versus Defense simulation procedure has been programmed for a large capacity electronic computer and first became operational in the summer of 1955. For the most complicated cases, a single run might take as long as three hours. However, many cases of interest have had run times of less than half an hour.

REFERENCE

(1) LUTHER, MARVIN, AND WALSH, JOHN E., "A Difficulty in Linear Programming for Transportation Problems," submitted for publication in *Naval Research Logistics Quarterly*.

Computerized Production Control

by **J. T. CLARK**

Production Manager, Poughkeepsie Plant, International Business Machines Corporation

THE problems of our production control are: too much inventory or not enough; and report information received too late to be of value. We all want technically developed requirements, planning and inventory control techniques, and management reports with information hours old instead of days or weeks. IBM at Poughkeepsie receives these benefits from utilizing a 705 data processing system in its production control operations.

Before we move further into the production control area, let's take a look at IBM Poughkeepsie—the plant and its products. The Poughkeepsie plant, one of five in the Data Processing Division, covers about one million square feet of floor space and employs some 5,700 personnel in the manufacture of electric accounting machines and data processing computers. Some of the products produced are keypunches, bank proofs and card sorters. We also make nearly all of the units comprising the 704 and 705 systems. It is one of these 705 systems which gives us "Computerized Production Control."

Now we'll consider the scope of Poughkeepsie's production control operation. At present, approximately one-third of the total plant inventory is represented by finished parts in stock. These parts make up our perpetual inventory which we call P.I. We control about 40,000 active parts, the majority of which are purchased. These parts include everything from a washer costing a few mills to a power supply unit costing $10,000.00.

PRODUCTION CONTROL FUNCTIONS

Here are some of the production control functions which the 705 performs for us. First, there is the development of material requirements which we do monthly or more frequently if a production schedule change so dictates. The basis for the development of material requirements is a production schedule covering a twelve-month period. This schedule is prepared and issued by top management. It tells us at Poughkeepsie the number of each type of machine we'll be expected to produce during the next 12 months. From this yearly schedule a monthly breakdown is made by machine type. We divide each machine type into features. A feature is a major assembly. The voltage group of a machine is a feature. One of six different voltage groups will be called for on a keypunch. Since several different features may be called for on a single machine type, we maintain a Sales Analysis File to give us the feature percentage breakdown for each machine type. From the production schedule and Sales Analysis File feature requirements are computed by the 705 in about one hour.

This breakdown information covers over 80 different machines involving some 800 features and is stored on magnetic tape. Next, miscellaneous and Field Service (or as we call them Customer Engineering) requirements are added to the requirements tape. Items such as replacement parts required by machines in the field are included in these categories. We should note here that we determine our Field Service requirements by using the least-squares method. The prediction is based upon actual usage in previous quarters and is run quarterly with monthly updating. The data is placed in a least-squares equation which develops a line of minimum variation. A prediction can then be made at any point along the line. After placing total planning requirements on tape, we are ready to compute the final sub-assembly and component requirements. But, first let us look at how we summarize the requirements for those parts used in several features.

BILL OF MATERIAL

A bill of material is a list of the parts which go directly into the making of a feature or other assembled part. Our bills of material are originated by the Engineering Department and maintained by Production Control Machine Accounting in punched card form, but placed on tape for requirement computations. By sorting our bill of material tapes into part number sequence, we have developed a "where-used" part list. A "where-used" part list shows the extent of a part's usage at IBM Poughkeepsie, while an orthodox parts list would only show the quantity of a part need for a single assembly. Of course, we update our bill of material and where-used tapes just prior to computing requirements. The 705 system generates component and sub-assembly requirements through to the lowest level, by successively exploding lower level bills of material. The lowest level is made up of basic components only. At present, we need not go beyond seven levels or generations; however, it is possible with IBM's machines growing more complex, that we may have to do so in the future.

PERPETUAL INVENTORY RECORD

After the 705 develops and summarizes our requirements for all parts and components, it reads them into the Perpetual Inventory record which we maintain for each part number. This 40,000 part number record which is stored on four reels of magnetic tape, is known as our P.I. record. How about the development of requirements for those parts used in higher assemblies? Do we take into consideration the fact that certain quantities of these parts may be available in a built-up assembly or are in the process of being built in order to prevent an unnecessary stock-piling of inventory? The answer to this is, "yes." The 705 performs two operations in this regard which were formerly nearly impossible; namely, netting and offsetting. Netting takes into account the fact that

TABLE 1

Month	Aug.	NOW ▽ Sep.	Oct.	Nov.	Dec.
Line 1—Part A	×	5	10	6	12
Line 2—Part C	5	10	6	12	×
Line 3—Part C	0	9	6	12	×

Available for Netting—6 of Part A

certain needed components have been or are being built-up into higher assemblies. Offsetting takes into account the time needed to build a level of sub-assembly, which is about one month in most cases.

Table 1 shows that as of September 1st, our monthly requirement for part A, line 1, a sub-assembly, is 5, 10, 6 and 12 for the ensuing four months. Part C, a component, is used in A in an exact one to one ratio. Therefore, in order to build five of part A in September, we would have to bring in five of part C in August, 10 in September, and so forth. Line 2 shows our offset requirements for part C. However, let us say we have six of part A in stock or available for netting. Line 3 shows our netted requirements for part C to be zero in August, 9 in September, and so forth.

Let's turn to the P.I. record for a moment. We have on tape approximately a 400 character record for each part number. It requires less than two inches of magnetic tape to record this entire record for a part. Some of the fields such as gross requirements are updated when requirements are run. Other fields such as receipts or withdrawals are updated daily. Approximately 10,000 transactions are processed daily. The 705 punches out a new P.I. Record Card for our production auditors when a change to any one of the 23 bits of information contained on the card occurs. The production auditors, therefore, receive as a result of the requirements run an updated P.I. Record Card for each part number affected.

ORDERING OF PARTS

We use an order point system as the basis for procuring parts. The order point is expressed in days and includes lead time and protective stock. Protective stock is the quantity maintained to provide a margin of safety in the event of unexpected withdrawals. When our days' coverage equals or falls below the order point, we place an order. How much do we order? The sales boys tell us to order enough so that we may never need to make a customer wait. On the other hand, however, our controller reminds us of the cost of maintaining this inventory. The 705 computes the happy medium!

If the part is purchased, the 705 computes an Economical Purchasing Quantity (EPQ). The EPQ may be manually refined to take advantage of quantity discounts offered by individual vendors. If the part is manufactured, the 705 computes an Economical Ordering Quantity (EOQ). The EOQ weighs the cost of possession, which includes storage and investment costs, against the cost of acquisition, which includes order and manufacturing costs.

In addition to determining the order point and quantity the 705 also tells the production auditors, by means of punched cards, when to expedite, cancel, or reschedule an order.

Now that we've taken a brief glimpse at how the 705 assists us in planning, ordering and scheduling, we'll turn to a discussion of how we measure the effectiveness of our computerized system. A few of the reports used in evaluating the production control operation will be shown.

PURCHASE COMMITMENT EVALUATION REPORT

Our first report is the Purchase Commitment Evaluation Report, Table 2. This report compares, by month, the purchased inventory we are scheduled to bring in with what we should bring in. Line 1 shows our forecast dollars. In order to arrive at a forecast, we subtract the stock on hand from the yearly requirements. If and when stock is insufficient to satisfy requirements, we forecast an order. The order dollars are placed in the monthly period when delivery should occur. If, for instance, we "depleted" the stock of a part with a once a year delivery schedule at the end of July, then August would show a year's requirement for the part. Line 2 indicates the dollar amount of the purchase orders placed with a vendor distributed into the delivery periods. Line 3 shows under-committed dollars. These figures are determined by subtracting the stock on hand from the yearly requirements. If and when stock is insufficient to satisfy requirements, we determine if a commitment is on record to cover requirements. If there is a commitment, it is subtracted from the requirements in the same manner as the stock was. If there is no commitment, the dollar amount of the prescribed delivery is reflected in the applicable month. Line 4 indicates over-committed dollars. These figures include those orders due to arrive before the protective stock level, plus an additional number of days, is reached. The amounts are distributed according to the month in which delivery is due.

Looking at the behind schedule column, we know that the $100,000.00 represents orders with past due delivery dates. We could request the 705 to give us a punch-out of the purchase order numbers making up this figure.

TABLE 2

Purchase Commitment Evaluation Report, May 30, 1958

Category	Behind Schedule	June 1958	July 1958
Line 1 Forecast	120,000	1,500,000	1,000,000
Line 2 Committed	100,000	1,600,000	1,050,000
Line 3 Under Committed	40,000	30,000	10,000
Line 4 Over Committed	5,000	80,000	70,000

Although our purchasing people would be responsible for taking the necessary follow-up on these orders, we give their expediting of certain orders considerable impetus when we point out the critical parts situations and possible line stoppages which are due to orders with past due delivery dates. At first glance it might seem that we would be under-committed by $20,000.00, the difference between the forecast and committed amounts. However, had the $100,000.00 in past due deliveries been made as scheduled, they would have not only reduced the behind schedule forecast but also the forecasts for the next several months. Delivery amounts are reflected in the committed portion and in most cases they are greater than the quantities needed to meet a month's needs. It is the under and over committed figures which weigh requirements, stock, and orders, and give us the information upon which we act. Undoubtedly, we'd get a 705 "punch-out" of those part numbers in under-committed status in order that we could take action.

Looking at June and July we find an over-committed situation exists in both months. After considering the detail behind these figures we might decide to have our purchase reschedule program run. This program would tell us which orders to reschedule with the new delivery dates. As you can see, we depend upon the Purchase Commitment Evaluation Report to give us both the current picture and trend of our purchased parts. It also serves as an aid to our budget people. The supplemental detail listings show us the part numbers and orders requiring action.

INVENTORY EVALUATION REPORT

Table 3 shows the Inventory Evaluation Report which measures our actual in-stock inventory against a calculated ideal or average inventory and a maximum inventory level. Average inventory is one half of the economical ordering quantity plus protective stock. Maximum inventory is the EOQ plus protective stock. This is because we know we never want to have any more in stock than the entire quantity of an economical order plus the protective stock. Let's look at the Inventory Evaluation Report for manufactured parts. Line 1 shows that in Product Zone 1 less than 10% of the part numbers are under protective stock or over maximum levels. Since our actual inventory is less than average inventory, this zone is in good shape. If, for instance, we had fifty or so items under protective stock levels, we'd realize that our seemingly ideal inventory position was being achieved at the risk of stock-cuts. We can see that such is not the case. Nonetheless, we could get a 705 punch-out of the 36 part numbers in order to check the action being taken on them. Line 2 indicates a little over 10% of the Zone 2 part numbers require attention. We recognize that to reduce our inventory, we'll have to concentrate on the 173 over-maximum parts. Line 3 shows Zone 3 to be in immediate need of corrective action. The Inventory Evaluation Report is a yardstick by which we measure the effectiveness of our inventory control operations. We're interested in knowing the cause of our problem situation in order to take the necessary preventative measures. For instance, is the Zone 3 problem due to schedule changes or inadequate analyzing? We sometimes find certain part numbers with a propensity for having stock levels under protective stock or above maximum. It may be determined that large unplanned field service withdrawals are being made. We'd then request our Customer Engineering Department to re-examine their requirements. In addition to those inventory evaluation reports broken down by product zones, we have them prepared by production auditor number, commodity codes such as motors or tubes, and so forth. One of the most important benefits we derive from these reports is the indication of inventory trends. We prepare graphs from most of these monthly reports in order to help us readily see developing trends. The 705 prints the Inventory Evaluation Report directly in about two hours. It took us nearly 6 weeks to produce this report using punched cards, and then the information was too old to be of good use. By being able to see almost as of the moment where dollars are being tied up by unnecessary inventory, Production Control management is able to act with great assurance. We've now seen how the Commitment Report aids us in controlling our purchased parts inventory on order and in process and how the Inventory Evaluation Report assists us in controlling inventory on hand in terms of requirements.

TABLE 3

Inventory Evaluation Report
Manufactured Parts

	Product Zone	Number of Part Nos.	Over Maximum	Under Protective Stock	Actual Inventory	Average Inventory	Maximum Inventory
Line 1	01	562	22	14	250,000	300,000	350,000
Line 2	02	2,078	173	56	700,000	600,000	800,000
Line 3	03	1,221	220	45	400,000	300,000	375,000

$$\text{Average Inventory} = \frac{EOQ}{2} + \text{P.S.}$$

$$\text{Maximum Inventory} = EOQ + \text{P.S.}$$

ROTATING INVENTORY REPORT

Our Rotating Inventory Reports, Table 4, measure our control of inventory on hand in terms of stock handling and record processing accuracy. Each month we count an increment of our part numbers. The frequency of count is based upon our monthly value requirement code which takes into account both the monthly requirement and unit cost of the part. Our report shows that 3,200, or 40%, of the stock balances tested during May were accurate (line 3). In some cases, of course, the P.I. quantity was greater than the bin quantity, while the opposite was also true (lines 1 and 2). Line 9 reflects the dollar activity since the last count on the 8,000 parts counted. Line 7 is

TABLE 4

Rotating Inventory Report, May 1958

Line 1	R.I. Counts Over P.I. Stock Balance	2,000
Line 2	R.I. Counts Under P.I. Stock Balances	2,800
Line 3	R.I. Counts Equal P.I. Stock Balances	3,200
Line 4	Total R.I. Counts	8,000
Line 5	Adjustment Value—R.I.C. Over P.I.	$ 200,000
Line 6	Adjustment value—R.I.C. Under P.I.	$ 244,000
Line 7	Gross Adjustment Value	$ 444,000
Line 8	Net Adjustment Value	$ 44,000
Line 9	Activity on Adjusted Items	$22,000,000
Line 10	Adjustment Ratio (G/I)	2.02%
Line 11	Target Ratio	2.00%

R.I. = Rotating Inventory.
R.I.C. = Rotating Inventory Counts.
P.I. = Perpetual Inventory Quantity.

the sum of the plus and minus adjustments to the P.I. (lines 5 and 6). By dividing the Gross Adjustment Value, line 7, by the Activity on Adjusted Items, line 9, we develop an Adjustment Ratio, line 10. Our aim is to have an adjustment ratio which is less than the Target Ratio of 2%, line 11. You can see we failed to meet our target in May. This Adjustment Radio gives Data Processing Headquarters management an easily applied yardstick by which they might measure our stock handling efficiency.

Table 5 shows us the magnitude of our errors. Lines 5 and 6 show us that less than 1% of our counts accounted for 85% of our gross adjustment. Lines 1 and 2 indicate over 90% of our counts accounted for less than 2% of the dollars adjusted. Investigators look into all adjustments for over $100.00 to determine the reasons for the errors. We are then better able to take corrective action. The corrective action, for instance, may take the form of temporary checkpoints or a new procedure aimed at improving an operation. It takes the 705 fifteen minutes each month to turn out the R.I. Report.

DAYS ADJUSTMENT REPORT

The first part of Table 6 gives us error frequency and amount, while part two shows the magnitude of the errors. But we must ask ourselves the further question of how bad are our errors in terms of requirements for the parts. In other words, a difference of 100 pieces between the physical and P.I. stock balances would be potentially more harmful to our operation if the requirement for the part was one a day rather than 50. In the former instance we'd be in the hole by a 100 days' requirement, while in the latter case it would be 2 days. The protective stock level for a particular part is based upon its monthly requirement value code. For instance, value code 1 items have a monthly dollar requirement of up to $50.00, while for value code 6 items the monthly dollar requirement is over $10,000.00. Our sample report is for value code 1 parts. Because of the low monthly dollar requirement for these parts, we order them only once a year and maintain a 60 day protective stock level. Looking at our example, we note that 1,000 counts resulted in a minus adjustment, that is, the stock on hand was less than the P.I. indicated. Assuming an average and median lead time of approximately 60 days, the order point for code 1 parts would be 120 days. Therefore, our report shows 10 parts which would have been depleted before the order point was reached. Fifty parts would have been approaching protective stock level before the order point was hit, and we may have been either out of stock or deep into protective stock by the time delivery was received. If the May report is representative, then approximately one out of every 50 value code 1 parts is in a critical situation in terms of requirements.

TABLE 5

	Size of Adjustment	Adjustment Dollars	Dollars Percent	Counts	Count Percent
Line 1	None	—0—	—0—	3,200	40.0
Line 2	$1–49	6,000	1.4	4,100	51.2
Line 3	$50–99	20,000	4.5	400	5.0
Line 4	$100–999	40,000	9.0	230	2.9
Line 5	$1,000–10,000	80,000	18.0	60	.8
Line 6	Over $10,000	298,000	67.1	10	.1
Totals		444,000	100.0	8,000	100.0

TABLE 6

May 1958—Value Code One Parts: Days Adjustment Report

Total Code One Parts Counted	3,000
P.I. Stock Balance Equaled Rotating Inventory Count	1,500
Minus Adj. (Stock on Hand Less Than P.I. Stock Balance)	1,000
Plus Adj. (Stock on Hand Greater Than P.I. Stock Balance)	500

Minus Adjustments *Days RQMTS.*	*Total*	*1–60 Days*	*61–120 Days*	*Over 120 Days*
No. of Counts	1,000	940	50	10
Percent of Total	100%	94%	5%	1%

MACHINE LOAD FORECAST REPORT

Let's now turn to our Machine Load Forecast Report. This report which the 705 turns out for us weekly in about three hours keeps management abreast of machine loading and scheduling problems. Let's took at how the data for the report is gathered. When the order point is reached, we know the 705 cuts an order card. Our Machine Accounting Department, upon receipt of the order card from the production auditor, matches it with the master routing deck which contains a card for each operation used in making the part. The master routing deck is reproduced into machine load and schedule cards. The stock date, set-up hours, and running times are considered and the start date for each operation is determined. Move tickets are prepared from the machine load and schedule cards, one for each operation.

The move tickets are placed with the manufacturing order which is released ten days prior to the job start date by the production auditor. The machine load and schedule cards are sent to the Manufacturing Control Department

TABLE 7

Machine Load Forecast Report—Part I

Line 1	001 0106 B and S Auto Screw			Cap. 5 75% 300 6/2 6/9 9/02				
	Shift	Tot.	Opr.	Work	Down	Tool	Other	Set-Up	Reset
Line 2 Non-Prod. Time	1st	44	—0—	—0—	16	8	—0—	14	6
	2nd	66	32	—0—	24	—0—	—0—	10	—0—
	Totals	110	32	—0—	40	8	—0—	24	6
		Total		Behind Sch.		On Sch.		Ahead of Sch.	
Line 3 Load Moved		15	410	2	61	12	290	1	49
		Out to Vendor		Outstanding		In Insp.		Accepted	
Line 4 Subcontract		1	26	11	222	1	18	7	159

TABLE 8

Machine Load Forecast Report—Part II

	Behind Sched.	Current Week	2nd Wk.	3rd Wk.	4th Wk.	5–6 Wks.	7–12 Wks.	Bal.	Total Hrs.
Line 1 Load as Sch.	61	334	242	204	155	121	366	28	1,511
Line 2 Sch. Load /Cap Load as Expect	.2	1.1	.8	.7	.5	.2	.2	—	5.0
Line 3 Avail to Run	—	308	220	170	0	20	82	28	828
Line 4 Coming in	—	—	109	34	155	101	284	—	683
Tot. Expected Load		308	329	204	155	121	366	28	1,511

where they are placed in an inactive file. As the job moves from one department to another, the dispatcher in the department receiving the job forwards the move ticket to the Manufacturing Control Department. Here the schedule card corresponding to the move ticket is removed from the inactive file and placed in the active file until the next move ticket is received. The schedule card is then placed in the load moved file. The dispatchers also process set-up and non-productive machine time cards to the Manufacturing Control Department. Weekly, the cards are converted into tape and the report is run.

The Machine Load Report is divided into two parts, Table 7 and 8. Moving across line 1 of Table 7, we note 001 as the department and 0106 as the machine group. A report is prepared for each of the 250 machine groups we have at Poughkeepsie. Machine group 0106 covers our Brown & Sharpe Automatic Screw Machines, of which we have five. Working five machines two shifts gives us a maximum capacity of 400 hours per week. However, since we adjust our capacity figure by an utilization factor, which in this case happens to be 75%, the report shows 300 hours. The historical data in the report is for the period from June 2 through June 9 and the forecast portion runs to September 2. Line 2 gives us the reasons for non-productive time. We had 44 hours of idle time on the first shift and 66 on the second. The first reason is no operator. This reason accounted for no hours on the first shift but 32 on the second. We may compare the second shift figure with previous weeks. Does it indicate, for instance, a need for a shift in personnel, or that the operator was used elsewhere on a different machine group? The next column is no work, and therefore is always scrutinized very carefully. We'd want to determine if the cause for no work was a production schedule change, an excessive number of screw machines or what. In examining most of these reasons a close consideration of previous reports is necessary in order to determine unfavorable trends. Of course, if we continually were faced with a figure for the next reason (machine breakdown) we'd better consider a major overhaul or new machine. The next reason is tool trouble, followed by "other," which is explained on the non-productive time cards. The details are readily available if desired by management. Line 3 tells us that we moved 15 jobs out of Department 001 on which 410 hours were worked. Twelve of these jobs were completed on schedule, one ahead and two behind schedule. Line 4 shows the sub-contract picture. One job was sent out during the week. This job would have taken us an estimated 26 hours to complete. Eleven jobs are outstanding, and one is in inspection. We accepted seven jobs, representing 222 hours of work during the week ending June 9.

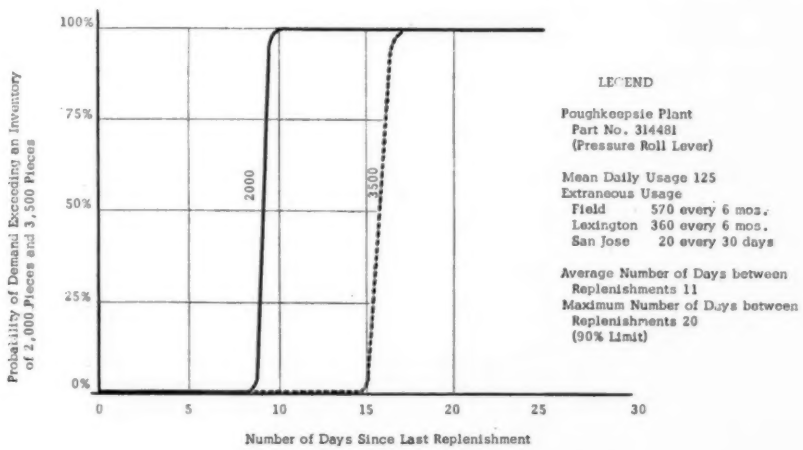

FIG. 1. Demand Curve

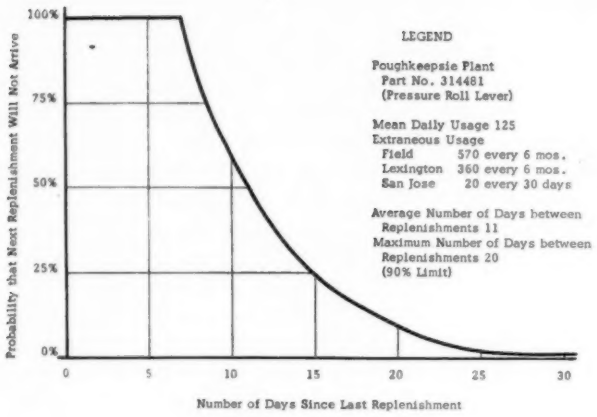

FIG. 2. Supply Curve

The second part of the report is the forecast portion and is based upon estimated hours, Table 8. Line 1 shows the number of hours scheduled to be completed in the period indicated based upon the calculations contained in the machine load cards. Operations scheduled for completion prior to June 9 but not yet finished would fall into the behind schedule category. Line 2 indicates the ratio of the hours scheduled to be done in each period by the capacity for that period. Line 3 shows the effect of rescheduling. The operations are distributed according to stock dates. Succeeding operations are put into a period in the machine group based upon when the operation of a particular order will fit. This is determined by the available capacity of the group and when the next prior operation of the order would be expected to be completed. Line 4 tells us what orders currently are at some other group but will be required in machine group 001 during what period. These figures may indicate a need to expedite certain orders in order that they may be available when needed. We can get a print-out of the jobs making up any of the categories we've seen.

The Machine Load Forecast Report is a valuable tool which allows us to:

1. Plan additional or transfer existing manpower for better utilization.
2. Measure and control department and total plant performance.
3. Measure the impact of and plan schedule changes (increases or decreases).
4. Plan additional or transfer existing machine tools for better utilization.
5. Effectively operate an organized sub-contract program.

In addition to the reports which I've touched upon, we use the 705 to compile and evaluate a multiplicity of other information. This may include a special study on the effect of varying delivery schedules on purchased parts inventory, or a tote box report which aids our internal trucking department in determining its container needs.

CALCULATING ADEQUATE INVENTORY

We've been looking at Poughkeepsie's production control system; its operation and the reports by which we evaluate it. The system is not static, but fluid in nature and under continuous evolution. Let's now take a look at one of the refinements we are considering making to the existing system; namely, the scientific determination of adequate inventory and protective stock levels. The order point system is based upon the assumption that the supply and demand patterns are both predictable and dependable. These assumptions are not entirely true, and therefore lead to such problems as expediting, rescheduling and uneconomical ordering. Recognizing the need for a more realistic reflection of the supply and demand functions in our system, our Operations Research Group, working with our methods people, is developing a mathematical procedure to show this. Using statistical sampling techniques, we hope soon to collect the data necessary for testing this procedure. Figure 1 shows graphically the demand for a part with both a fixed inventory of 2,000 and 3,500 pieces. We can see that the greater the initial inventory the less probability there is of running out of stock in a fixed period of time. Figure 2 shows the supply pattern for the same part. Ninety percent of the time an order will arrive within 20 days, while the average number of days between replenishments is 11. There is a 100% probability that replenishment will not arrive in 7 days and a 10% probability for 20 days. Figure 3 superimposes the demand curve over the supply curve. With an inventory level of 2,000 pieces there is a 60% probability that we'd be out of stock in 10 days, since our demand would have depleted the supply with only a 60% probability of non-replenishment. With an inventory of 3,500 pieces there is a 15% probability of being out of stock in 17 days, since by then our supply would be depleted with a 15% probability of non-replenishment. Figure 4 shows the probability of a stock-out for varying inventory levels. At the 2,000 piece level it's 60%, while at 3,500 pieces it's 15%. From this graph we can determine the dollars

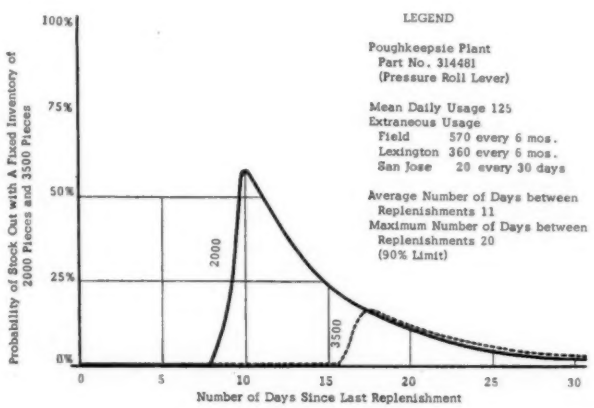

FIG. 3 Stock-Out Curve No. 1

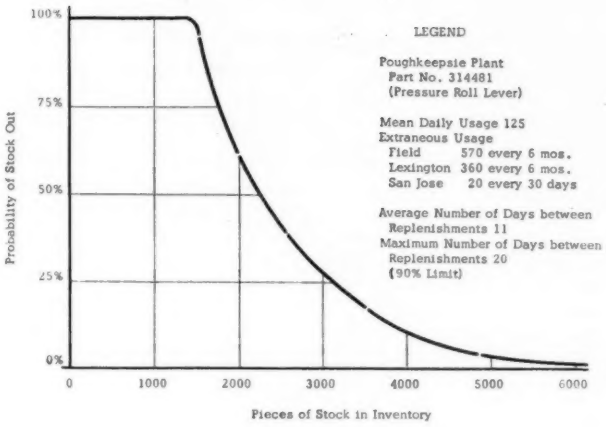

FIG. 4 Stock-Out Curve No. 2

we must maintain in this part to give us the protection we desire. We do not have an automatically computed stock level, but rather a management tool to assist us in deciding what level of stock we will maintain. We've seen but one small refinement to the production control system. Others like it are in the process of development.

SUMMARY

Plant management by utilizing the 705 has been given greatly increased capability for effective decision making. Although we have realized definite monetary savings from our computerized production control operations, a strict dollar and cent evaluation can't be made. We have gained the use of data formerly unavailable and other needed information with amazing accuracy and speed. We like to think of our greatest benefit as timely and current formation, available to aid us in making decisions. We recently made a dollar study of the area and found that no matter what yardsticks we applied the monetary savings were greater than the cost of utilizing the 705.

EDP-The Fourth Dimension of Productivity

Multiplying Defense Capabilities

by **CHARLES A. PHILLIPS**

Director, Data Systems Research Staff, Office of Assistant Secretary of Defense

ELECTRONIC Data Processing will contribute during the next few decades tremendous advances in productivity through reduction in the time cycle required for the production of goods and services. I shall confine my discussion to the use of Electronic Data Procesing in increasing Defense productivity, and will stay generally within my field of responsibility—the use of these systems in business-type operations. In brief, I will try to cover the following:

1. Why and how we began to use Automatic Data Processing in our business operations.
2. Something of the management philosophy we have applied.
3. A summary of some of our applications.
4. Some of our problems and plans.

THE NEED

Defense has almost a vested interest in electronic computers. Through Army sponsored research during World War II, the first all-electronic computer, the ENIAC, was built for the Ballistic Research Laboratory at Aberdeen, which continued to be used until this spring. The need for such a computer and some of its components was the result of "Manhattan Project" calculations which had emphasized the need for increased speeds and capacities of computers for scientific efforts. From this beginning, the military departments continued to extend their use of electronic digital computers in the scientific and engineering field and a high proportion of the "one-of-a-kind" computers, such as the NORC, the JOHNNIAC, and the RAYDAC, with high speeds and capacities, are in military installations or had their genesis and financial support under military projects or contracts.

Just as a telescope is an indispensable tool of the astronomer, so is the electronic computer an indispensable tool of today's scientist, engineer, and mathematician. I would not attempt to assess and give credit to the part computers have played in the tremendous technological developments that have taken place within the past ten years, but we do know that the present size, scope, and character of the Defense effort would not have been possible without them. Technological efforts are continuing at an accelerated pace, particularly since the importance of scientific progress to the Nation's military strength was suddenly and dramatically brought to public attention by the successful launching of the first Russian satellite on October 4 of last year.

HISTORICAL INSIGHT

The use of computers in research programs of the late 1940's and early 1950's gave Defense first-hand knowledge of their speed and other capabilities and an insight

into their potentials for management purposes. Our business management problems are big ones. In fact, the Department of Defense is a unique establishment with no counterpart in modern business. Its activities spread through 48 states, 16,000 cities, and 52 foreign countries. In terms of dollars, its expenditures represent about 60% of all Federal expenditures or one-seventh of our entire national income. In terms of personnel, it employs over four million people and, if you include reservists, retired personnel, and foreign nations, the total is eight million people. In terms of property, physical assets are twice that of the one hundred largest manufacturing corporations in the United States approximating in real and personal property, $140 billion. We are, in fact, Big Business.

OPERATIONAL TO SUPPORT

A continuing and increasing difficult problem in defense management is the ratio between the military operating (combat) forces and support forces, including civilian employees. Business and industry have a comparable problem in the ratio of clerical, maintenance, and other overhead employees to factory or productive employees. In Defense this problem has been particularly difficult since the Korean War. The size of Army operational units has been reduced with the increased firepower of new weapons that include guided missiles, rockets, and nuclear capable units. Fewer Naval vessels with the greater striking force of nuclear power and guided missiles result in fewer combat personnel. Fewer Navy aircraft of higher performance and armed with improved air-to-air missiles have improved the kill capability. The Air Force is going through a major technological transition—changing importantly the composition of the forces and achieving greater combat power with a lesser number of military personnel and units. At the same time, the increasing complexity of these modern weapons requires additional maintenance and support effort. However, during the period of greatest change, from 1953 to 1957, with a continual and gradual reduction in total personnel, the ratio increased only two percent. The reduction of support personnel is one of the prime objectives in the adoption of automatic data processing systems in Defense and, with a few exceptions, our installations show a reduction, or a projected reduction, of personnel. In one application, 485 positions were eliminated. While this was an unusual case, it encourages us to believe this may be the answer to at least part of our problem by substituting *machine minutes or seconds for man-hours.*

QUALITY OF INFORMATION

Another objective is to improve the quality of information. A decision or conclusion is usually no better than the information upon which it is based. This is fundamental, but in practice we become overwhelmed with the volume of data when we consider a multitude of factors. Mr. W. J. McNeil, Assistant Secretary of Defense (Comptroller), made a statement before a conference which I think is appropriate here:

> Before leaving the subject of management information, I would like to mention what I shall call data reduction, a term usually associated with scientific and engineering calculations, but with a connotation that I think should be applied to business data processing. These new data processing systems give us the ability to drown management with information—an ability we must not use. Too much information can be almost as bad as not enough. Fortunately, this equipment also makes it possible to summarize and select the significant and sensitive information that management can use and needs for informed decision making. Through this data reduction capacity of the equipment, we can turn the flood of data which management can't use to a flow of selected, integrated, significant facts on which sound decisions can be quickly made.

This leads us logically to the management philosophy of "management by exception" which has almost fallen into disrepute. Here is where automatic data processing can make a major contribution. With tremendous speed, storage capacities, and ability to make routine decisions, it can select for management those problems requiring judgment of a higher order. No matter how large and complex the operation, it can make "management by exception" a reality instead of a theory.

PAPER REDUCTION

There is another potential that we should make every effort to exploit. This is the ability to reduce paper volume. I have no idea of the quantity of paper that goes into our Pentagon paper mill, but I do know that we destroy 28 bales of it every day. With this new capability, we can compress and store information efficiently and cheaply, and avoid the preparation of many intermediate records. Most clerical operations generate some kind of paper output, but this is minimized in a computer which follows long sequences of operations without human intervention. If intermediate results are needed for audit or record purposes, they are readily available.

THE SYSTEMS CONCEPT

One more point and then I'll get down to some specific applications. The speed, capacity, and versatility of these new machines require management to take a hard look ats its present philosophy and practices. Management must begin to think more in terms of the whole enterprise instead of by functional areas or locations. Many jobs or functions will need to be re-engineered and this need can be met only by an increased emphasis on systems engineering. The capability of modern data processing equipment can provide for the development of truly *integrated* management systems. Let me illustrate this concept. Once a bit of information is introduced into the system (that is, recorded, written, or copied) it can be rearranged, summarized, printed, or otherwise manipulated with a minimum of human intervention. By making the original information in some form which can be recognized and acted upon by the equipment, we can obtain

many advantages, not the least of which is a reduction in human error.

Now let's look at how Defense is using electronic data processing systems in four general categories of business-type application.

The largest area of application is that of material management. By this we mean stock control and distribution, requirements determination, cataloging, and the other related functions needed to procure, store, and issue supplies and spare parts. Some of these applications are quite complex and interesting and I will describe several of them later.

The second largest area of application is in the field of personnel information. Private industry has only a limited need for this type of application while there is probably no other area in which Defense has a greater need for complete, appropriate, timely, and accurate data. When fully operational, our personnel information systems will provide extensive information on the skills of our personnel, their present status and distribution, projected gains and losses, and other data needed to manage our manpower resources.

The third largest area of application is financial, statistical services, and payroll. In industry, payroll is probably the primary reason for most applications. In Defense we don't have any instances where it has been the principal application and the reason for this difference is our payroll operation is less complex and expensive. However, there will be a substantial development in the financial and statistical area within the next few years to meet increasing requirements for better management information with which to establish realistic price tags for programs, introduce economic incentives, and satisfy the needs of Congress.

The fourth area of application is described as integrated operations. One example is an application at the local level which includes all of the data processing requirements of the various functional areas of management and captures data in machine language for repetitive use wherever needed. This is an area of limited application to date but in which we expect to see considable progress in the next few years. In addition to the integration of different functions in a single organization, we have the problem in Defense of tying together organizations at different locations but in the same functional area. An example of this is in the area of material management where there are interactions between base level, distribution depots, supply and stock control points, and catalog agency. All of the advantages of integration at a single location are present plus an additional advantage. By putting data in machine language we can speed the transmission greatly where speed is needed and worth the additional cost.

BID EVALUATION

A case that illustrates an unusual application of management analysis is a bid evaluation developed by the Bureau of Standards for the Army Quartemaster Corps. Under contracts for military uniforms, the Government furnishes the contractor with the materials. The contractor bids on a variety of sizes for several different garments and for delivery to a number of Defense supply depots. There are as many as 10 variables on one bid and bids are frequently received from 20 or more bidders. The required analysis by manual methods requires an average of 4,000 man-hours for each award whereas on a computer all combinations and all contracts and all variations can be calculated in forty minutes of machine time. This, of course, is exclusive of time required to prepare the data for machine application.

AIRCRAFT MODIFICATION

Another application is that of control of aircraft modification for the B-52 and KC-135 aircraft. This is a problem of rapid equipment obsolescence. The modification program of an airplane begins early in its development and there may be several hundred changes before the first airplane is delivered. If changes can be made during manufacture, the contractor advises the Government with a change report. If the modification has not been made before the airplane is delivered, it requires a "retrofit" program which is accomplished by contract, field command, or depot using "retrofit" kits. No two airplanes in the production line necessarily will be delivered with identical specifications. Before planning the "retrofit" program, it was necessary to know exactly what changes had been accomplished before delivery. An accurate and completely up-to-the-minute specification of the aircraft as delivered was required to establish an accurate "retrofit" program and speed up the operational availability of new aircraft. Although the basic data covering changes made during manufacture was currently supplied by the contractor, our previous data processing systems were inadequate and we spent millions of dollars inspecting airplanes to determine the required modifications. This delayed the "retrofit" program and the operational use of the aircraft. The Air Force tried a program of control for the B-52 and KC-135 airplanes utilizing the high speeds and large storage capacity of a large-scale computer. This application had not been anticipated or programmed when the computer installation was originally justified and approved. Now, when a B-52 or KC-135 is delivered, a report is immediately available showing all modifications made during manufacture plus a complete and detailed "retrofit" program for that specific aircraft. This phase of the application alone has saved the total costs of the automatic data processing system and what is more important it has put airplanes in operation at an earlier date.

ENGINE MANAGEMENT

The worldwide Air Force inventory comprises 100,000

engines with a value in excess of $6 billion. Management needs to know: number and type of engine; where they are; and their condition status. Information must be collected and kept up-to-date from 500 Air Force reporting installations worldwide. The objective is to obtain minimum inventory investment through effective distribution of spare engines, computation of accurate requirement and buying programs, and improvement of engine overhaul schedules. Statistics are developed for parts and components causing engines out of commission, failures resulting from material deficiencies, actuarial engine failure rates, and actuarial engine life expectancy factors. This task was previously performed by a combination of punched card and manual methods, but the costs were high and results were often too little and too late. Under the new system, a direct report on an individual engine serial number basis is made from each Base to a central Data Processing Center covering every change daily as it occurs in the status of an aircraft engine. Initial test of the plan was made on control of J-47 jet engines. The test was successful and the system is being expanded to cover all types of aircraft engines. Both direct and indirect cost savings and other benefits have been obtained. Nearly 100 man-years of clerical work have already been eliminated with a saving of over 500 man-years expected when fully implemented. Estimates of the reduction in engine requirements through better inventory management are in millions of dollars.

PARTS ALLOWANCE LISTS

Another application has been in the preparation of Ships Parts Allowance Lists. Lists are prepared to cover repair parts for more than 70,000 different equipment components. These lists and related publications prescribe what part to use for each repair job and what spare parts are to be carried on ship. Items are selected for inclusion based on the specific equipment installed on each type of ship and the extent of experienced repetitive demand. In addition, a few "insurance type" items are stocked. A large-scale data processor is used in performing this inventory management function including procurement and distribution of ships parts throughout the world and the preparation of consolidated stock status reports, allowance lists, parts lists, and various other reports. The effectiveness of ships parts supply support to the fleet has been measurably improved through the speeding up of information on inventories and requirements. A 30-day reduction in lead time has been one result which has permitted a substantial reduction in re-order quantities. Navy officials estimate that one-time savings from the 30-day reduction in inventory level will eventually exceed $6 million. The new reports average only 5 to 15% of the volume of earlier types of reports.

FAILURE REPORTING

Another application has been in failure reporting of electronic equipment. A large computer devoted primarily to scientific purposes has also been used to process reports on electronic component failures. Failures of such components as tubes, resistors, and condensers are reported from the field. This application has produced analyses of electronic tube failures by various categories, such as manufacturer, equipment model, use of the component in a particular circuit, and environmental conditions. The benefits have been: 1. faster tabulations (seven to ten days sooner than with punched cards); and 2. reporting by exception. This use of the principle of management by exception limits the printing out in a report to those equipment failures in a few critical components or which have been excessive according to a predetermined rule. The new reports average only 5 to 15% of the volume of earlier type of reports and engineers are now able to direct attention promptly to significant trouble areas and institute remedial action.

PRODUCTION CONTROL

A proposed application currently being developed is a production control system, which is a joint effort at two of the Naval Air Stations, Alameda and North Island. Initial planning has been directed to the overhaul and repair activity. In brief, the system consists of placing the production planning data into the computer, generating individual shop orders, recording work transactions on these orders, feeding the data back to the computer, updating the planning data by these transactions, and printing out summary completion and status reports on aircarft overhaul and repair.

DATA TRANSMISSION

The eventual extent and effectiveness of automatic data processing in an organization as vast as Defense will depend in a large part on solving the data transmission problems between different locations. At the present time we transfer data between locations by four methods: 1. transmission of punched cards by mail; 2. wire transmission of punched cards by transceiver; 3. mail and wire transmission of punched paper tape; and 4. mail transmission of magnetic tape. All three of the military departments have extensive transceiver networks. This means of transmittal of data is very widely used. Since experience has shown that we can save money and improve operations by transferring data between our installations in machine language, it makes sense to extend these same techniques to our Defense contractors. We are trying it in a few areas, and today thirteen contractors and eight Defense agencies talk to each other in machine language. To be more specific, the agencies and contractors exchange information in connection with the provisioning operation in the form of punched cards, punched paper tape, or magnetic tape. We also exchange technical data by this technique. In addition, information as to contract status, shipments, and deliveries is also ex-

changed. Most of this data exchange is by mail transmission of punched cards although we have two contractors in our transceiver network and will probably add others this year. The solution of one problem often leads to another and in the case of machine language data transfer, we have two additional problems: 1. the speed of transmission using transceivers, approximately 11 cards per minute on land lines, is too slow for our traffic volume; 2. different installations within the same functional area use data processing equipment made by different manufacturers which use different internal machine language. A plan which may solve both problems is a device to convert machine language of any make of equipment to communication pulses, send these pulses over telephone lines or radio, and then reverse the process at the other end. The idea was presented to several manufacturers last year and one of them has prototype equipment now under test. As a further development, it is expected that tape-input and output to the communication system may soon be possible.

BALLISTIC MISSILE

Another proposed application of unusual significance is with the new ballistic missile systems. The complexities of these new weapons compound our logistics problems. One of the systems alone consists of 1.5 million components and parts. Not only is the problem large and complex, but our national survival might depend on our ability to effectively support such weapons. A concept has been developed using the weapons systems management approach to the problem of logistics support of ballistics missiles. An automatic data processing center will provide current up-to-the-second information on requirements and cut red tape and reduce records to a minimum. Operational squadrons will be supplied automatically, based on periodic reports with priority items sent by aircraft. The missile units will be linked with the weapons systems manager by a data processing center and two-way wire communications encompassing the storage sites and the contractor's plants. During the early test operational stages, contractors will provide the direct supply support of the squadrons.

RISING COSTS

During this discussion, I have referred a number of times to the rising costs of defense weapons. It appears that weapon costs will continue to rise rapidly for some time, independently of price increases caused by inflationary pressures. The best illustration of this trend is in the cost of aircraft which takes about half the dollars spent for major items of equipment. The average cost per aircraft for the Air Force and Navy has tripled over the last six or seven years. There are many reasons for this striking increase in unit costs—heavier aircraft, more electronic equipment, higher speed, greater range, increased armament, and a general increase in complexity. A little history and some of the current developments will illustrate this problem. During World War II, for example, the cost of aircarft averaged about $10 a pound. During the Korean War the cost per pound was about $25. The high performance airplanes now being delivered cost $50 per pound. For aircraft to be delivered two or three years from now, the cost per pound will probably run from $70 to $80. The complexity of high performance combat aircraft may be appreciated when their cost per pound is compared with the cost of pure silver which is less than $15 per pound. The jet and rocket age has imposed vastly increased demands upon research and development programs. These development costs are over and above the costs of equipping our forces with currently available weapons and must be carried simultaneously, which places a double burden on the Defense budget. Such tremendous requirements for defense funds to provide the Armed Forces with modern weapons provide an incentive for the maximum application of automatic data processing so that a greater proportion of the available funds will go for weapons rather than the support function.

SUMMARY

Defense pioneered the use of electronic computers for scientific purposes and is now engaged in a comprehensive and aggressive, but carefully controlled, program for applying the time compression potential of electronic computers to the business-type activities of Defense. We have made substantial progress to date but know that we are just scratching the surface. The productivity of dollars devoted to defense will rise sharply as we gain experience in these new techniques. As taxpayers and citizens, you will receive many benefits from these applications in "more defense per dollar." As Industrial Engineers, concerned with immediate applications to increase industrial productivity in your own organization, you now have available equipment and techniques made possible by past investments in defense. With your training and experience and this new capability, automatic data processing can, in fact, become the fourth dimension of productivity.

EDP—Its Impact on Jobs, Procedures and People

by **J. DOUGLAS ELLIOTT**
Director of Central Data Processing, The Detroit Edison Company

BY WAY of background, Detroit Edison has about 1,250,000 customers spread over 7500 square miles of territory. We have about 11,000 employees. In October 1953 our management decided to review our total customer accounting and collecting area of activity. This is a

rather large area in a public utility and deals with reading meters, billing accounts, applying payments, maintaining customer records, answering customer inquiries, and collecting from the customer who is reluctant to pay his electric bill. We have about 1,000 employees involved in this job. We wanted to see how we could reduce costs in this area; improve our procedures in order to maintain or improve our relationship with our customers; and we wanted to design and organize a system so that we would be ready to utilize electronic equipment, eventually.

The study continued for 14 months, and during this period it became apparent that we could move into electronics right away. This study did not start as an electronics feasibility study—it started primarily as an economic study. We reviewed all phases of this area of operation. In addition to combining many of our clerical operations and record keeping functions on the computer, we made many other changes.

This is a volume operation. Our daily work requires reading 35,000 meters, billing 35,000 accounts, applying 40,000 payments to those accounts, and making 5,000 basic changes to the records. This work lends itself to the use of automatic equipment. However, as I will point out later, there are many exceptions to this area which make it rather difficult.

Among other things, this study proposed to consolidate three telephone groups that talk to customers; to completely revise our account numbering system; and to eliminate or consolidate much of our customer record keeping. We had more than 9,000,000 records made up of six basic customer records. These were maintained in five filing systems in four departments and were arranged in three different sequences. At the same time we planned to consolidate three company groups that talk to the customers in the field about general billing inquiries, verifying meter readings, collecting bills, and the like. I tell you this to point out the broad changes we made and to make certain that you understand that this does not just concern the installation of a computer, for many other changes could have been made without the computer. However, we must confess that the computer prepared us for getting this job done. We thought that it would help overcome resistance. I think it did, but it had its hazards.

COMPUTER INSTALLATION

We selected the IBM 705 and recruited our first batch of programmers in January 1954. We knew little about programmers or about testing them. Of the original 25 programmers (we still have 25 programmers) only 4 are still programming. Nevertheless, after some 45 man years of programming and system planning (that brings us up to February of last year), we decided that we were ready to start converting our accounts to the new system. The programming group had written something under 30,000 instructions to operate this system at that time. In addition, they had to write another 20,000 instructions just to take care of the special conversion routines. We thought we were ready to proceed with our computer installation.

Of course, it isn't like changing a system on an assembly line in one of the Detroit automobile plants, where you can build a new assembly line and push a button one morning and everything is on a new system. We had to convert gradually because we had to keep the bills going out to our customers so we could keep the money coming in. We planned a 9-month conversion period which actually took 14 months. Very careful planning was necessary to make not only the change to the computer but also to make other clerical changes. In fact, some of these clerical changes were well under way when we started converting. We completed conversion last month, and now we expect that it will take us about a year to polish off the system.

At the moment, we are utilizing the computer only for the billing of our accounts and maintaining of our customer records. Remember, the study started in October 1953 and it will be another year before we are through. However, we are now beginning to plan and will soon start programming our employee data handling operation, including payroll, inventory control, and other activities.

Now, let's analyze what we have done from a standpoint of procedures, jobs, and people. First, I might say that Detroit Edison has had a long history of automation in its office operations; in fact, we started to automate exactly 40 years ago by using Addressograph plates instead of writing in longhand the names and addresses on customers' bills. Just prior to the conversion to the 705 computer, we were using two IBM 650's for some of our bill calculation operation. They succeeded IBM 604's.

We have made changes in field, telephone, and clerical operations, and have consolidated record keeping on magnetic tape. We changed from a specialized plan of customer bookkeeping to a station plan of customer bookkeeping and feel that all of this has greatly simplified our system. In other words, we have simplified our work by consolidating our operations. We found that programming the operations for the computer was much more complex than we had anticipated. We also found that we didn't realize the amount of individual judgment that was being used by employees who were handling exceptions to the system. I mentioned that we had nearly 30,000 program instructions when we started converting. In spite of all our testing before we got into conversion, we began to realize that many of the exceptions were overlooked. Likwise, we realized the importance of building into the program many checks and controls we hadn't had before. We have actually increased our program instructions by approximately 40% from the day we started converting to the day we finished converting. We now have well over 40,000 instructions just to handle this customer record system in addition to the 20,000 to take care of conversion which is now complete. However, as a result, we have a system that is much more accurate and much

more tightly controlled than we ever had before. We learned by experience, but we are very proud of our system. It is running beautifully.

JOB EVALUATION

What did this change do to our jobs? First, I mentioned that we had simplified the work. But, I also mentioned that we had consolidated many operations. This, of course, resulted in the enlargement of jobs. Really, work simplification and job enlargement are compatible. We did anticipate, and I did some predicting about it, that the average wage level of our people would go up because we enlarged jobs. We finished the evaluation of our jobs last month. Many jobs were deleted, many were changed and enlarged, and some were added. It turned out that the average grade level or wage level of our jobs is about the same as it was in the beginning. This excludes the programmers. We have a large staff of programmers and console operators now. If we include them, the average wage will go up. But, that doesn't help the average office employee because we seldom recruit our programmers from file clerks, key punch operators, etc. We get them from other areas in the company. So, we didn't obtain what we hoped we would obtain for our people. We did reduce our work force, somewhat. And, we reduced our number of job classifications by about 50%.

What else did it do to jobs? Well, it created so many new and changed jobs that about 90% of the people working in this area (and that's about 400 clerical people) had to learn a major part of their job or a new job all over again. We have another 500 people who are indirectly related to the computer (talking to customers, answering their inquiries, on field operations, collecting delinquent bills and that sort of thing). They, too, had to adjust and orient themselves.

Likewise, we had to increase our number of people and create many temporary jobs because, during conversion, we actually had three systems in operation. We had to have X number of people operating the old system, X number of people operating the new system, and X number of people working on the conversion operations. So in order to install a computer to reduce our work force, we had to increase our work force by 60 people.

EFFECT ON PEOPLE

I would like to say what all this has to do with people. Naturally, our folks wanted to work on this new system, not the old system or temporary procedures. Obviously, everyone couldn't be permitted to do so. We had to keep a nucleus of trained people on the old system; we had to put very good people on the temporary one; and, of course, we had to train others on the new system. So, in order to encourage our people to cooperate, we made a commitment that once the conversion was over we would throw open all of the jobs in the new system for bidding. We feel that this is only fair to our people. We have promised that those people who have worked on and have had experience on the new system will not get preferential consideration. Incidentally, we don't have an office union, and if we continue to be conscious of our people's needs, as we are attempting to do, they might not feel the need for one.

All of these things have a direct effect on people. But, there is an indirect effect also, for people are afraid of electronics. Detroit Edison has established a policy that no employee will be laid off as a result of technological improvement. As a result, nobody will lose his job. However, we shouldn't be naive enough to think this solves all of our problems. Even though an employee knows that he has job security he worries about other things. He may have to learn a job all over again; maybe he has performed this job for 20 years and now has to start all over by learning another job at 62 years of age. Also, he may have to work for a new boss, and possibly work in a new department or work on a new shift. It is normal, therefore, for employees to resist change.

Now, in the area of resistance to change, I want to talk first about the people who are most directly related to the computer, organizationally. This involves some 400 people whose jobs to some extent have to do with the input to the system, the output from the system, or the operation of the system. Remember, we did not just install a computer. We changed clerical work groups and many company policies. We also did a tremendous amount of reorganization, not only at the worker level and work group level, but by shifting responsibility between departments and between management executives. We thought we would attempt to overcome resistance to change among those more closely related to the computer by continuing what we had always been taught to do; that is, to keep the communication line open vertically and horizontally by keeping people well informed as to what was going on. Also, we had long had a policy of participative management—of having the employees participate in the decision making by getting together with their boss to talk things through. This proved to be quite successful. Employees made sacrifices, and they worked overtime when they didn't want to work overtime.

However, in another area not so directly related to the computer, the people involved appeared to resist the change to a greater extent (a few hundred people are involved in this area). The fact that these people were indirectly related to the new system led us to believe that training, detailed communications, and participation was not necessary. These were the people who had to talk to our customers and in general were concerned primarily with customer relations matters. As you know, you don't install a system like this without increasing errors during the transition period. These people, whom we did not orient completely, were somewhat resentful because some of their decision making was now being done by the computer or standardized by policy changes. They did not

understand the reason for many changes made in policy and procedures. This resentment resulted in accusations, the magnification of errors, and frictions between the less oriented employees contacting the customers and the more oriented employees maintaining the accounts. It also resulted in much challenging of procedures, which had been approved by their own superiors in this indirect area of responsibility.

EVALUATION

This became quite serious. People were talking about "this 705 system." Feelings became so intense that top management people began to be quite concerned about the adequacy of the new system. Just after the first of this year, our President decided that the whole matter should be looked into. Consequently, outside consultants were hired to evaluate the system. Of course, it is quite a letdown after you've gone through a change of this magnitude to have it questioned as to adequacy.

I mentioned that the computer would act as a catalyst to get many of the changes made. How true this was! The computer got more than its share of the blame. Questions were commonly asked, such as:

1. When are you going to get rid of the machine?
2. How is the machine working today?
3. Why does the machine make so many errors?

To date, errors caused by the machine have been practically nil. All errors have been traced to human failures or misunderstanding. Yet the machine or system was blamed.

Last week, the consultants made a report to management. They said that no more errors were made during the conversion period than would normally be expected under any system change of this size. They also said that the system is running smoothly and that they saw no reason to recommend any significant change in procedures or any change in personnel. It turned out to be a vote of confidence. The consultants did make some good recommendations, but these were more organizational, policy, or managerial in nature rather than procedural.

The University of Michigan Research Center also did some research for us in connection with the entire change on people. They pointed out that the basic trouble was insufficient communications and training among employees and inadequate opportunities to participate in the change and to know what was going on. We had decided that it was not necessary to work with the employees in this indirect area. The result of our misjudgment almost threw our installation. If our President had not had the foresight to call in consultants to evaluate this, he may very well have asked us to take out the system. This indeed would have been unfortunate when the basic fault was the inability of people to adjust to the change. Today, our system is operating more accurately and more rapidly than any previous system. Furthermore, it will soon be operating more efficiently.

SUMMARY

So, what did the computer do to procedures, jobs and people? It simplified procedures by consolidating our operations. While the internal procedures on the computer were much more complex than we had expected, we have a tighter control. It enlarged the jobs in connection with simplifying the work. We have fewer job classifications, and the wage level has not changed.

We are not, however, able to so easily capsule our thinking about what the computer did to people. This is a continuing work. We all understand the direct effect the installation of any major change, particularly computers, has on jobs, the people, their pay, their working hours, and whom they work for in the organization. But we also have to be aware of human emotions—getting people to participate and keeping the communication lines open to overcome resistance, and making them aware of the fact that these machines are not masters of men.

We know we have much to learn about computers. They're in their infancy. They have a long way to go. But I venture to say that we know less about the human brain than we know about the electronic brain today. We should keep this in mind in our dealings with our people.

I recently asked my boss, the chief accounting officer, what came to his mind when he thought of this change. During our conversation he listed his thoughts in this order: emphasis put on the customer complaints received; the enthusiasm and cooperation we received from our people who worked closely with the computer; the time he had to spend thinking through the organizational changes that had to be made at the department head level and up; the personal and social sacrifices that were made by all of the supervisors in order to give their time to the installation of this system; and his own tendency in 1953 and 1954 to underestimate the magnitude of the job. He spent some time in carefully considering there thoughts before finally stating them. After he discussed these thoughts with me, I asked him about his views on costs and hardware. He explained that he had not included costs because it was evident that hoped for savings would eventually be realized and that he considered hardware a minor factor in such an installation.

In a sermon a couple of months ago my minister related our physical being—our physical self with our inner self. He pointed out that our inner or spiritual self is more important than our physical self. I couldn't help but relate that to an EDP System. It's not the computer standing in that nice computer room, it's not the flow chart on the wall, but it's the human endeavor behind it that counts.

Increased Profits in Small Plants

Improved Manufacturing Controls

by **N. A. LAMBERTI**

Vice President and General Manager, Ryder-Elliott, Inc., Inglewood, California

EVERY business magazine or daily newspaper one picks up today reflects discussions on the readjustment of our business economy. Most companies are reducing their capital expenditures, inventories and plans for expansion. Sales are off, profit margins down and costs are still increasing.

Certainly there are a lot of areas in which a company's management can improve its situation in this present competitive era. One of the greatest opportunities to put a company in a profitable position is in its ability to reduce and control costs.

There has been a lot written on ways and means of reducing costs, too much of which is specialized, applying only to large companies and reflecting only refinements to a present system. It appears that in a small sized business (one which lacks the army of staff personnel of a large company) one of the areas to effect the greatest cost savings is through efficient manufacturing controls.

In small businesses, decisions lie in the hands of a few persons. These "key" employees usually have a lot of important information in their heads. In the event one of these key employees is sick or leaves the company, there isn't enough knowledge in writing on procedures or techniques of his particular job to make available to subordinates to efficiently run the company. This aspect is most critical in controlling costs in small businesses. Controls, techniques and procedures must be established, on paper, to assure the continuity and satisfactory performance of a small business.

SYSTEMATIZATION

Such cost programs as the suggestion plan, wage incentive plan, work simplification plan, and other specialized approaches are certainly necessary and rewarding. However, the biggest area (for small plants) to reduce costs and increase profits is in the systematization of operations; whereby a series of reports are set up containing all aspects of the company's operations and which pass over the manager's desk for him to analyze. In addition, from these reports, job knowledge must be passed on to foremen so that they too are informed and can make decisions.

It has been my good fortune, while an executive in a large company, to have spearheaded a team which acquired four subsidiaries. From these experiences, and others encountered through my teaching, it was apparent that small businesses did not have the necessary planning, procedures and controls to successfully run an operation. My present position, as Vice President and General Manager of a company employing 250 people, has enabled me to apply the following techniques, which have substantially reduced our costs.

AN EXAMPLE

Our company has grown from 80 to 250 employees, in which two key people ran the company by the seat of their pants. Now, procedures are in effect so that the foremen run the operation and top management is left to analyze reports, make plans and important decisions. We make 30 different items of tubular furniture in approximately 150 combinations. Our production capacity is 2000 pieces per day in a 75,000 square foot plant.

First of all, the general manager or the owner of the company should prepare an annual sales and financial forecast. This is the target or goal the company is to strive for. Also, it sets the stage for all the important decisions as to products, designs, tooling, equipment, man power, etc.

The manufacturing division has the majority of the manpower and needs the most techniques in order to control it properly. The manufacturing cycle begins with the issuance of a manufacturing forecast prepared from the sales forecast. Regardless of the sales forecast, it is the responsibility of manufacturing to keep controls and records necessary to reconcile orders, backlog, inventories and shipments, and never produce above these requirements. This is an important check and balance situation.

The single biggest department in which savings can be made is in purchasing. There is a purchasing evolution in existence today which is stressing the important role that this department now plays. In a majority of companies, 55 to 60 percent of the company's sales dollar is spent by the purchasing department for goods and services produced by others. With labor only about 10 to 12 percent of sales, a 2 percent savings in purchasing is equivalent to a 10 percent decrease in labor. Manufacture controls as I will describe them are broken down into three categories.

1. Raw Materials Controls (Purchasing)
2. Work in Process Control (Production)
3. Finished Goods Controls (Sales)

PURCHASING CONTROLS

Bill of Materials—A formalized form should be drawn up, listing all part numbers, their description, quantities, and whether they are to be produced in or outside the

plant. In addition, this same form can be used for pulling assembly and fabrication parts to a schedule, and to cost out the company's products. This complete record helps one to analyze the material cost with intention of reducing it. It will also prevent the ordering of wrong parts or quantities which result in incorrect and expensive inventories. From this, a bill of materials spread sheet by category can be made for the entire product line of the company, and passed on to manufacturing supervisors.

Purchase Requisition—Many companies, who have repetitive production, unfortunately still do not use a repeating, hard copy requisition. This type form of a requisition is a tremendous time saver; giving the buyer more historical data on the part to be purchased—thus eliminating chances of error. This form is basically a hard copy form, with all the pertinent information filled out on it: such as 1. part number; 2. name; 3. type, weight, etc; 4. assembly used on; 5. quantity per assembly; 6. packaging information; etc. In addition, there is room on the card for about ten buys of the part, that is, the card can be used over and over again, lasting, normally, for about two to three years purchases. This, of course, eliminates the need for a buyer to issue and write up a complete new paper requisition each time.

Raw Materials Inventory Control (Kardex)—Proper procedure in the control of inventories allows the minimum amount of money to be invested at all times. When materials are ordered to manufacturing forecasts, the kardex is referred to for the "on hand" and "on order" balances. Incorrect and/or incomplete data results in costly errors of surplus and obsolete inventories. It is estimated that the charges on carrying an inventory are 25%.

Inventory control records are the focal point of planning in the attempt to run a manufacturing operation successfully. It is said that about 15% of business failures can be attributed to the problems connected to uncontrolled inventories.

PRODUCTION CONTROLS

Shop Manufacturing Outline—These shop manufacturing outlines, or operation sheets, completely describe the manufacturing sequences, tools, machines, etc., used to make the part. In addition, the setup and running time for each sequence is shown. These time standards serve as a means of scheduling manpower in the shop and show labor costs to be used in figuring the cost of the product. This type of information reduces costs in manufacturing in that it provides for a planned, orderly system of producing the product. Everything is stipulated, leaving no room for guesswork. Errors in manufacturing, resulting in lost labor and excessive scrap, are minimized.

Production Schedules—From the manufacturing forecast, detailed departmental schedules are drawn up. Untold costly errors have been made in the past by many companies who informally, or verbally, release their schedules to the producing departments. A schedule serves many purposes. It completely indoctrinates the departments in "job knowledge" about the product, and it establishes quantities and the time required to produce them. Supervisors who post to their schedules are continually informed of the quantities and parts in process and are, therefore, better able to meet management's forecasts.

Production Reports—The supervisors' reports must come back to production control or management as to what is being produced. This stimulates departments into doing a better job in meeting their production quotas. In addition, these reports serve as the basis of calculation on the labor efficiency in the department. This sets the stage for analyzing manpower costs by department and by operation.

Job Tickets—These labor tickets are made by the "direct" labor employee. This lets them know that they are being measured. It also serves as a basis for figuring the actual labor costs in calculating the labor efficiency. With this job control in effect, it paces the worker and definitely allows the company to get a full days work out of the employee.

Labor Performance and Distribution Report—This report analyzes the efficiency of the shop labor. By using the production reports, job tickets and time standards, a complete performance breakdown by part, product and department can be made. This, of course, also includes an analysis of the indirect labor. With these data, operations and equipment can be analyzed, employee performance can be checked, product labor costs recorded, and complete manufacturing costs can be collected.

Manpower Report—Management should have a weekly, or perhaps a by-monthly report on the distribution of labor by department. This enables a comparison with actual figures and those forecasted on goods being produced and shipped.

PRODUCT INVENTORY CONTROLS

Daily Orders Recap—Incoming orders by product, color, type, etc. give management a clue on customer likes and dislikes. In addition, it is possible to compare orders with the sales and manufacturing releases. This enables management to reconcile any differences with manufacturing schedules and thus not build up inventories which tie up the company's capital.

Daily Shipments Report—This report enables management to see if forecasted daily and monthly sales are being met. A company's breakeven point, and manufacturing forecast, are predicated on a certain volume of sales.

Finished Goods Inventory and Order Backlog Report—In many ways, this report controls the complete operation. From this data, production schedules, manpower and shipments are reconciled with the sales forecast. Changes in the manufacturing forecast are made from the order backlog report and the finished goods report

tells us what we have on hand to ship against pending orders. These reports also contain information as to color, model, type, quantity and product. It is evident that from these reports one can be flexible and can intelligently make any necessary changes to meet customer demands. The reconciliation of schedules, orders, shipments, production, inventories, and backlog from this report allows for an efficient and economic control of all costs involved in the manufacturing division.

SUMMARY

The above procedures have been put into effect in our company. They are not complex, all supervisors readily understand them and use them daily for making decisions. Certainly many of the same techniques are applicable to larger companies. To carry out these controls, the company must have strong administration and management. In other words, cost reduction programs, reports, procedures, etc., are no substitute for good management in controlling costs. This is especially true in small businesses, where the top planning responsibility lies in a few hands. However, the ideas and techniques as outlined above, have been used most successfully in small businesses, and certainly supplement and form a basis for continuity for its present management. These techniques allow the company to periodically gather facts and have them interpreted. In turn, these facts and analyses insure that intelligent decisions will be made to effectively control costs.

Sales and Contracts

by **DONALD L. DRISCOLL**

Vice President, Sales and Contracts, Cal-Tronics Corporation, Los Angeles

ACCORDING to the Small Business Administration, "small business" is one in which less than 500 people are employed. The designation is important since a certain portion of government spending each year is channelled to businesses of this category. In the electronic business, small firms are especially anxious to attract as many of these sales dollars as possible, either as prime or subcontractors.

ORGANIZATION

Now let us briefly review the sales and contracts organization within our electronics plant employing from 150 to 200 people. Sales, contracts and estimating have been placed under one head who reports directly to the general manager. The combination of these three activities results in very close control over all requirements concerned with the customer. The invitation to quote, the estimate, actual bid and contract are all funnelled through one head. Activity on each contract is also closely checked by this same manager on a daily basis. This is done very easily by a quick review of a "Daily Profit and Loss Statement," which we have now been using for several years. It reflects not only all of the cost data for any given contract, but also the production volume and schedule adherence. It might interest you to know that this form of daily reporting on all contracts of any consequence costs us one-half of a man day to compile. The volume of business being reported varies from $150,000 to $200,000 per month. While this report is of obvious importance to other departments in the firm, it has proven to be very valuable to all phases of the sales and contracts activity. By 9:30 each morning we know everything that has occurred the previous day on all contracts that are or should be in work. Of prime interest to the Sales team is the schedule position of each job.

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Assuming that your company is not well known to the buyers to be contacted, it is well to prepare and have ready for their study, written and pictorial exhibits on your activity. These should include a products and services outline, information on your manufacturing and engineering personnel, financial statement, security clearances, pictures of your plant and products, organization chart, an outline of current and past customers including the services performed and any other information that you feel might be of interest in "selling" your company. After you are armed with these displays, you must select the buyer of the product or service which you wish to sell. This is done by either contacting friends within that plant who are acquainted with the various buyers or by consulting a buyers list usually available in the purchas-

plant. In addition, this same form can be used for pulling assembly and fabrication parts to a schedule, and to cost out the company's products. This complete record helps one to analyze the material cost with intention of reducing it. It will also prevent the ordering of wrong parts or quantities which result in incorrect and expensive inventories. From this, a bill of materials spread sheet by category can be made for the entire product line of the company, and passed on to manufacturing supervisors.

Purchase Requisition—Many companies, who have repetitive production, unfortunately still do not use a repeating, hard copy requisition. This type form of a requisition is a tremendous time saver; giving the buyer more historical data on the part to be purchased—thus eliminating chances of error. This form is basically a hard copy form, with all the pertinent information filled out on it: such as 1. part number; 2. name; 3. type, weight, etc; 4. assembly used on; 5. quantity per assembly; 6. packaging information; etc. In addition, there is room on the card for about ten buys of the part, that is, the card can be used over and over again, lasting, normally, for about two to three years purchases. This, of course, eliminates the need for a buyer to issue and write up a complete new paper requisition each time.

Raw Materials Inventory Control (Kardex)—Proper procedure in the control of inventories allows the minimum amount of money to be invested at all times. When materials are ordered to manufacturing forecasts, the kardex is referred to for the "on hand" and "on order" balances. Incorrect and/or incomplete data results in costly errors of surplus and obsolete inventories. It is estimated that the charges on carrying an inventory are 25%.

Inventory control records are the focal point of planning in the attempt to run a manufacturing operation successfully. It is said that about 15% of business failures can be attributed to the problems connected to uncontrolled inventories.

PRODUCTION CONTROLS

Shop Manufacturing Outline—These shop manufacturing outlines, or operation sheets, completely describe the manufacturing sequences, tools, machines, etc., used to make the part. In addition, the setup and running time for each sequence is shown. These time standards serve as a means of scheduling manpower in the shop and show labor costs to be used in figuring the cost of the product. This type of information reduces costs in manufacturing in that it provides for a planned, orderly system of producing the product. Everything is stipulated, leaving no room for guesswork. Errors in manufacturing, resulting in lost labor and excessive scrap, are minimized.

Production Schedules—From the manufacturing forecast, detailed departmental schedules are drawn up. Untold costly errors have been made in the past by many companies who informally, or verbally, release their schedules to the producing departments. A schedule serves many purposes. It completely indoctrinates the departments in "job knowledge" about the product, and it establishes quantities and the time required to produce them. Supervisors who post to their schedules are continually informed of the quantities and parts in process and are, therefore, better able to meet management's forecasts.

Production Reports—The supervisors' reports must come back to production control or management as to what is being produced. This stimulates departments into doing a better job in meeting their production quotas. In addition, these reports serve as the basis of calculation on the labor efficiency in the department. This sets the stage for analyzing manpower costs by department and by operation.

Job Tickets—These labor tickets are made by the "direct" labor employee. This lets them know that they are being measured. It also serves as a basis for figuring the actual labor costs in calculating the labor efficiency. With this job control in effect, it paces the worker and definitely allows the company to get a full days work out of the employee.

Labor Performance and Distribution Report—This report analyzes the efficiency of the shop labor. By using the production reports, job tickets and time standards, a complete performance breakdown by part, product and department can be made. This, of course, also includes an analysis of the indirect labor. With these data, operations and equipment can be analyzed, employee performance can be checked, product labor costs recorded, and complete manufacturing costs can be collected.

Manpower Report—Management should have a weekly, or perhaps a by-monthly report on the distribution of labor by department. This enables a comparison with actual figures and those forecasted on goods being produced and shipped.

PRODUCT INVENTORY CONTROLS

Daily Orders Recap—Incoming orders by product, color, type, etc. give management a clue on customer likes and dislikes. In addition, it is possible to compare orders with the sales and manufacturing releases. This enables management to reconcile any differences with manufacturing schedules and thus not build up inventories which tie up the company's capital.

Daily Shipments Report—This report enables management to see if forecasted daily and monthly sales are being met. A company's breakeven point, and manufacturing forecast, are predicated on a certain volume of sales.

Finished Goods Inventory and Order Backlog Report—In many ways, this report controls the complete operation. From this data, production schedules, manpower and shipments are reconciled with the sales forecast. Changes in the manufacturing forecast are made from the order backlog report and the finished goods report

tells us what we have on hand to ship against pending orders. These reports also contain information as to color, model, type, quantity and product. It is evident that from these reports one can be flexible and can intelligently make any necessary changes to meet customer demands. The reconciliation of schedules, orders, shipments, production, inventories, and backlog from this report allows for an efficient and economic control of all costs involved in the manufacturing division.

SUMMARY

The above procedures have been put into effect in our company. They are not complex, all supervisors readily understand them and use them daily for making decisions. Certainly many of the same techniques are applicable to larger companies. To carry out these controls, the company must have strong administration and management. In other words, cost reduction programs, reports, procedures, etc., are no substitute for good management in controlling costs. This is especially true in small businesses, where the top planning responsibility lies in a few hands. However, the ideas and techniques as outlined above, have been used most successfully in small businesses, and certainly supplement and form a basis for continuity for its present management. These techniques allow the company to periodically gather facts and have them interpreted. In turn, these facts and analyses insure that intelligent decisions will be made to effectively control costs.

Sales and Contracts

by **DONALD L. DRISCOLL**

Vice President, Sales and Contracts, Cal-Tronics Corporation, Los Angeles

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ing lobby. Having selected your buyer, you are now ready for step two: meeting him personally and initiating your sales campaign. There are several ways in which you can meet the buyer who purchases your product or service.

The *Cold approach* is to walk in to the vendor's lobby, without an appointment, hand your card to the receptionist, and announce that you are here to meet Mr. Cold Buyer. Mr. Cold Buyer may reply, through the receptionist, that he is very busy, tied up, in a conference, or otherwise too busy to see you. Or he may only be Mr. Cool Buyer, and will make a brief appearance in the lobby, shake your hand rather reluctantly, listen to your story for a discreet two minutes, apologize for not having need for anything in your line, and suggest that he will call you if something comes up. In either case, you made a cold approach, and received a cold reception. You deserved it.

The *Business Approach* is to call the buyer on the phone, introduce yourself and your company, and ask for an appointment at which time you can take 15 to 30 minutes to show him your company's capabilities. Suggest that it will give him an opportunity to see if your company or your product can be of service to him. Mr. Business Buyer will either say "yes" or "no." If your approach has been warm and cordial, most likely he will say yes, and you have yourself an appointment. If he says no, and proceeds to give you reasons, accept his rejection momentarily and suggest that you will send him some information about your company that can be placed on file for future reference. Then write Mr. Business Buyer a cordial letter, outline what your company product or service can do for him, and suggest that you will call again to go over the information more fully if it is to his best interest. If your letter is sincere and your company information worthwhile, chances are you will get your appointment.

The third method we will call the *Friendly Approach*. Find a friend who can introduce you to a friend, who can buy what you have to sell. The preferred method is to have "Friend" personally introduce you to Mr. Friendly Buyer. If this cannot be arranged, have "Friend" call Mr. Friendly Buyer and lay the ground work for your call. Then when you call for an appointment you can say with pride and confidence, "Friend sent me." This third approach always gets an appointment; then the sale is up to you.

You are now ready to use the ammunition gathered in step one to convince the buyer that he needs the products or services which your company will be happy to provide. A friendly non-high pressure exposure of your company, an appreciation of the buyers procurement needs, and a genuine desire to be of assistance, sincerely expressed, will usually generate the basis required to take you to step three. Charlie Brower in his "Age of the Goof-Off" sermon at the annual convention of the National Sales Executives said of the great salesman "He possesses the knowledge that everyone in the world wants to be liked and appreciated and helped." If you have given the buyer the feeling that your company can help him you will be invited to qualify as a vendor.

Step three, becoming an Approved Vendor, follows a very similar pattern in all companies. You are first visited by a quality control team, at the buyers request, who will review your equipment, personnel, quality control manual and records. Next your financial statements, banking connections and general stability is checked by the customer's financial group. Finally, representatives from manufacturing and/or engineering will review your facility. If the buyer receives favorable reports from all of these groups, you will be placed on the AVL, Approved Vendors List, and your real selling now begins.

The next step in your sales effort is to obtain Request for Quotation. Generally speaking, when a buyer receives a requirement for a product or service, he will give or send out quotation requests to from three to ten of the companies appearing on his AVL. In many instances he will have had recommendations on one or two of these companies from the department using the product or service. This is especially true when dealing in engineering services. *You* can uncover requirements prior to their reaching the buyer by searching them out through friends in the customers plant or tips from people in or out of your plant who have acquired knowledge of these projects. You can be the recommended vendor by a thorough, but discrete, sales job on the people working the projects involved. This is most effectively done by first obtaining permission of the buyer to discuss those requirements with the people concerned. Most buyers resent working or selling within the company without their knowledge and blessing. Whether or not you are a recommended vendor, if you are among those who get a quotation request, you have scored a partial victory. In most cases *price* will determine which company gets the purchase order.

Now comes the magic portion of sales and contracts: the right price. It must be high enough to make the desired profit and low enough to get the job. Since good crystal balls are hard to come by, we resort to the next best: the estimating team. They are charged with the important price considerations and generally speaking, the almost equally important conditions (and exceptions if any) under which the contract would be acceptable. Once a price has been established, discussions are held with planning and manufacturing for delivery commitments and concurrence on price and any conditions or exceptions involved. If the project contains engineering activity, the engineering department is contacted to help with conditions and exceptions. When complete agreement with all parties concerned is reached, the actual proposal and bid is prepared. This is probably the most important step in the sales and contract operation. Not only will the bid de-

termine the success or failure of the sale but if done correctly, it will result in a trouble free contract. Most troublesome contracts are caused by inadequate attention to conditions, deviations and exceptions during the proposal stage of negotiations. Among the more important conditions to be carefully discussed in the proposal are: method of delivery and acceptance; proprietary interests; type of contract; method of payment; and exact work content. Thoroughly test out every part of your bid; see that it is realistic and attainable. *Then, return the bid on schedule.* You must get the bid in on time. If there is some major reason to be late with your bid, be sure to ask your customer for approval of a late bid. If he does not approve, then either submit a "NO BID" return or somehow get the bid in on the date required. Within a few days after bid opening date, you will be notified that you did or did not receive the award.

The Purchase Order is in two parts: the original, and the acknowledgement copy. As long as you have both copies of that Purchase Order you do not have a contract and you are not legally bound to any of its provisions. But, as soon as you have signed the acknowledgement copy and returned it to your customer, you have a contract. You are then legally committed to fulfill every term of the contract as it appears on your copy of the purchase order. While you have both copies of the purchase order in your possession is the time to read the fine print as well as the bold type. There is more to this instrument than the quantity, the part number and the price. Check your purchase order carefully to see that it is written exactly as you bid it. Go over every detail that you had covered in your bid for any deviation in specifications, acceptance, payment, cost breakdown, delivery, proprietary interests, material status, costs, liabilities for non-performance, or any deviations from what you expected to receive on the basis of your bid. These fine points can be corrected much easier before you sign the acknowledgement copy than after. Then, return the acknowledgment copy as quickly as possible. Your customer must know whether or not you have accepted the job under the terms called out in his contract.

CONTRACTS

Generally speaking, the types of contracts in which we are interested fall into two broad classifications. These are Prime and Sub-Contracts. Prime contracts are of lesser importance to the small businessman in electronics because of the limited availability and the high cost of sale and administration. We usually associate the term Prime Contract with a purchase order from the government and in this area, most common are contracts with the armed services. As such, all of the ground rules regarding this type of contracting is found in the publications listed under "Armed Services Procurement Regulations."

Sub-contracts are of more interest to the small business man. These are purchase orders from the large prime contractors and generally are one of four types. These include: 1. Fixed Price; 2. Redeterminable; 3. Time and Material; and 4. Best Effort.

The Fixed price Contract is the type most often used. Except for costs generated by customer requested changes to the product, the vendor is paid the exact price noted on the original contract. This type of contract is generally used where competitive bidding for some product or service is possible. Depending on the size of the order and the number of available competing companies, bids are requested from three to ten or twelve vendors. If the best two or three bids are fairly close price-wise, the buyer may elect to ask the department within his facility for recommendations as to the most desirable vendor. Generally, however, the buyer will have picked vendors with commensurate facilities and abilities which resolves the choice to one of price alone. Proprietary (or sole source) items may be bought on a fixed price contract if the vendor insists and the buyer needs that product. Vendors with high profit products will always favor this type of contract, since they are allowed to keep any profit they make and are involved with much less accounting and justification reporting.

A Redeterminable Contract is one where a target and usually a ceiling price are set at the time of contracting. Also established at this time, and within the target price, is a cost breakdown which spells out such factors as Material, Labor, Overhead, G & A and Profit. At the completion of the job, the vendors books are audited and contract price adjusted within the ceiling limitations. The most used variation of this type sub-contract in our local area is one which calls out a "10% upward and no limit downward" redetermination. This means that the upper limits (ceiling Price) of the contract would be the target price plus 10%. The lower limit could be any amount. As an example, let us say that we have such a contract for 100 sub assemblies at $100.00 each (target Price). Assuming that in our cost breakdown (as noted on our bid) we had estimated our profit to be 10% on the project, our audited profit should be $1,000.00. Suppose the audit actually reflected a profit of $2,000.00. The customer would then request a refund of $1,000.00 on the monies billed and paid on this contract. Let us now assume that instead of making a $1,000.00 profit, the project resulted in a $800.00 loss. In this case we would be allowed a price increase up to $1,000.00 or 10% of the total contract price. Notice that I said up to $1,000.00. Many times, due to disallowances in some of the cost factors such as overhead or G & A, the price increase would be something less than the 10% stipulated. However, the "no limit downward" clause is the part of this contract to watch with care. Many companies get into real trouble with this one. The usual mistake is not to have a close tab on project costs as the job progresses.

Example: A Company has a "no limit downward" type

redeterminable contract. They are delivering units per schedule; billing and being paid target prices as called out on the purchase order. They know that they are making money, but not the exact rate. Most small companies can readily find use for available cash and this company has spent or invested the money resulting from billings on this contract as units were shipped. At the end of the contract they suddenly find that they owe a large refund to the customer: money that they do not have readily available. Now they are in two kinds of trouble: the obvious financial problem; and, unless refund is immediate, they have generated a sales impediment.

When is the redeterminable contract used? It is used in cases where the scope of the work is not too well defined and can not be very accurately estimated. Another use is where the product is not proprietary and is a single source item. However, may I suggest that as a vendor, avoid redeterminable contracts wherever possible, especially if the scope of work is well enough defined to result in confidence in your estimates.

Time and Material Contracts are next on our list. This type of contract is utilized in several sets of circumstances. Among these may be included the following: 1. Short run sub-assemblies produced from sketches where the work content is not well defined; 2. Short run production parts or assemblies on an emergency basis (no time for estimating and bidding); 3. Jobs where engineering changes are made more frequently than is commensurate with good production and contracting practice (many preproduction runs are made on this basis); and 4. As a safety valve for shop loading purposes of the customer plant. Here is a case where it is more economical to sub-let work to relieve shop overload on a short run basis than to hire and release additional employees.

As the name infers, this type of contract spells out the number of labor dollars and hours plus the amount of material money involved. Work is sent to the vendor in increments of varying sizes and is billed at the completion of each increment. When the limits of the contract are approached, the vendor notifies the customer and he will in turn increase the order, write a new one, or discontinue sending work when the limit has been reached.

Purchase orders of this type are usually obtained by bidding (sometimes competitively). The bid may be one of two types: either a composite rate; or a cost breakdown form of quote. The composite rate is the more simple and, unfortunately, the least used. In this type of bid, an average is taken of all rate classifications. The average is then increased by estimated overhead, G & A, and profit factors. The result is your composite labor bid rate. The cost breakdown, or classification type, bid outlines the labor rate for each classification expected to be used on the project. Each rate is then increased by overhead, G & A, and profit factors and becomes the bid rate for that classification. Material is handled in the same manner for either type of bid. Generally, it is the actual cost of the material used plus G & A and profit. In a few cases the customer will insist on being charged only the exact cost of materials used. This latter case usually occurs when the material to labor ratio is low.

A Best Efforts Contract is the type least often used. It is applicable in cases where the customer has a product idea that he wants developed, but neither he nor the vendor is able to predict the costs involved. Many times they are not even able to predict the probability of accomplishment of the desired result. As you may have guessed, the work content is usually engineering of the research and development type. Bidding for this kind of contract is much the same as was explained for a time and material contract. However, a Best Efforts vendor is chosen mostly because of a unique ability that he might possess, with far less regard to rates involved. A contract of this type specifies the job to be done and the amount of money to be expended. When the vendor reaches the cost limitations, he presents the desired product, in whatever stage of completion he has reached, to the customer and the contract is finished. Payment may be made in increments or in total at the termination of the contract.

All of the sub contract types discussed, excepting the fixed price classifications, are audited at completion. For this reason they involve much more reporting and take a lot longer to conclude after product shipment. Profit ratios on the fixed price contract are generally higher since once the price is established any savings generated on a given project need not be returned by the vendor. For these reasons, the fixed price contract is the more desirable wherever possible.

CONTRACT MAINTENANCE

Assuming that the purchase order you have received reflects all the conditions noted in your bid, you start off with a nice clean job. In electronics, as the job progresses, customer requested changes usually occur, changing the scope of work involved. Whenever this happens, your contracts man must immediately be advised so that monetary and/or schedule revisions to the purchase order may be made, and *made when they occur.* Contracts that have doubled and tripled in price because of changes are not at all uncommon. Unless he is advised as these changes occur, the customer somehow looks on the new costs with disbelief when billed at the end of a project. In most cases he will allow only part of these additional charges, making the vendor absorb the difference. Don't wait. Collecting changes at the end of a contract can be business suicide.

SUMMARY

In sales—be a good Industrial Engineer—convince the prospective user that the product of your ideas is exactly what he needs. In contracts—be sure that the original says what you mean—then maintain the contract.

Psychology and Productivity

Functional Supervision

by **HARRY L. CODERRE**
Partner, Rohrer, Hibler & Replogle

BEFORE proceeding to a discussion of supervision, it might be well to outline the conceptual premises upon which this talk is based. I believe in "working with" rather than "working over" people. This means that people should have the opportunity to grow and develop in accordance with their abilities and attitudes. I am deliberately appending the word "attitudes" because I believe firmly that the inflexible and the obstructionistic can penalize a common enterprise just as significantly as those who lack certain abilities. I believe that people should have the right to make mistakes, for only in so doing can they really grow. I believe also that people should be encouraged to make suggestions and that these, whenever possible, should be honored with answers. I am in favor of participation but I believe that the extent of this participation constitutes a privilege which has to be earned as the individual demonstrates his capability, his good judgment, and his discretion. These latter three qualities can only be evaluated, however, as individuals are given responsibility and granted authority. The business climate of today demands its share of quick decisions. I believe that certain of these decisions must be made by "management" or by its chosen representatives, because only they have access to a body of information which can never be completely disseminated. I should, in any event, question the wisdom of unselectively disseminating all information even if it were possible. Just as leadership necessitates the making of certain decisions, it also calls for the implementing of those decisions and this, in turn, demands that someone assume responsibility for follow-up and control. Further, I shall be completely realistic and say that I see no immediate prospect of eliminating injustice from the business environment. The foibles of human behavior make it inevitable that someone, in failing to do what he should do or in acting from false motives, will precipitate certain responses which will hurt or penalize a number of people.

MEANINGFUL SUPERVISION

You have already noted that the foregoing concepts place high emphasis upon responsibility and initiative. Indeed, the varied activity requisite for meaningful supervision provides rather marked contrast to the quasi-passivity implicit in the literal translation of the Latin *supervisus* to the English *oversee*. A large part of this activity focuses upon mass means of increasing or, at least, maintaining productivity. Admittedly, this sometimes takes a rather bizarre form. The story is told of the American manager of a production unit in Central America who was able to attract native help quickly by paying them far more than the going wage. He was appalled to find that they all were planning to quit within two months because they would then have been able to meet their financial needs for the ensuing year. He is supposed to have turned defeat into victory by distributing mail-order catalogues with glowing illustrations and thus set the stage for expanding their felt needs.

But if there is continued preoccupation with mass stimuli (and the present frenzied race in motivational research convinces us that such is the case) there is, happily, an increasing part of supervision being devoted to activity of a highly individualized kind. Individualized because not only must the supervisor involve himself in getting the job done with ever-improved effectiveness but, in so doing, he must be concerned with developing others who will be prepared to do it equally well. Present corporate demands for managers far outstrip the supply of those who, without guidance or assistance from others, can develop the abilities and attitudes needed in successful supervisors. And it is becoming increasingly apparent that advanced courses, seminars, and meetings will never compensate for this lack.

It was initially indicated that the supervisor encounters many variables which should influence his handling of situations from one time to the next. This statement runs the risk of positing "free action" which does not exist in all cases. While it is desirable that supervision be associated with an autonomy which allows unrestricted operation within the boundaries of defined responsibility and authority, we must recognize that supervision, as an entity, is always influenced by four factors: 1. the on-going general economy; 2. the organization within which the supervision is practiced; 3. the *mores* of those being supervised; and 4. the make-up of those supervising.

Our major concern is with the last-named of those four factors. In passing, however, we shall make some reference to the other three because we believe that top managment can appraise corporate supervision adequately only as that management is fully aware of the particular environment within which the supervision operates.

THE GENERAL ECONOMY

For instance, the present recessional economy has led to firings and layoffs which, in turn, necessitate realignment of duties and functions. Not only does such a readjust-

ment cause a temporary lag in communications but it may affect productivity even more directly by causing a gap in categories of skills in which remaining people have to be trained immediately. And it is quite probable that the scare induced by this kind of economy forces a general "no hire" order even though all heads may be unanimous in agreeing that a specially-trained person should be brought in to guide a certain project which has high priority.

Prosperity, on the other hand, may encourage unplanned expansion with the eventual result of pushing people upwards into positions for which they are either inadequate or unprepared. One end of this situation is to spread experienced supervision extremely thin and to free that supervision to take on peripheral responsibilities without accompanying authority. Aside from the general economy, sudden changes in technology and demand may bring about dislocations in specific industries.

ORGANIZATION

The organization itself exercises an even more pervasive influence upon supervision than does the economy. Each company seems to develop a particular kind of temperament which evolves from what it does, where it does it, how it originally functioned, and who was instrumental in guiding it. Over the years it becomes exceedingly difficult to identify the specific source which accounts for certain corporate actions. But we can often make a fair "guesstimate" that obsessions with a particular kind of promptness or loyalty spring from the values system of a community where the company was started, or from a person or persons powerful in the development of the enterprise. How much more insidious this is when some individuals attempt to establish themselves as the interpreters of what the founder would have done and saying "Old J. B. would never have approved of this" are merely reflecting "We don't have the guts to do what J. B. would have done in similar circumstances."

Whatever the sources, we can make an excellent case for the fact that some corporations consistently reflect equivocation and vacillation in policy-making, a failure to make decisions, a preoccupation with minutiae, and a disinclination to utilize the skills which flourish within their very environment. We don't need to enlarge upon the ways in which all of these weaknesses debilitate forceful supervision.

MAKE-UP OF THOSE SUPERVISED

Yet another factor which influences supervision is the makup of those who are supervised. The allusion, in this instance, is to the overall *mores* of the group rather than to the behavior of individuals. The militancy with which the supervised group presses grievances, the particular concept of seniority it embraces, the indifference or disdain it manifests in reacting to the objectives of management may all contribute to drawing unduly upon the supervisor's time and holding him from other pressing responsibilities. It is quite a revelation to note the wide disparity one finds from company to company in time devoted to industrial relations matters. And it is reassuring to discover that there are businesses where mutual trust between labor and management exists to such a degree that difficulties can be ironed out clearly and incisively.

ABILITIES OF A SUPERVISOR

None of the three factors mentioned above, however, can detract from the idea that it is the supervisor himself who is mainly responsible for the continuity of operation in any given company. We can all rattle off the various attributes which effective supervisors should possess. One of the interesting aspects of job descriptions and specifications is that, by implication they distinguish the various levels of supervision only in degree of abilities needed. It is this very matter of differentiating between, say adequate initiative and consistent initiative or between ingeniousness and creativity that provides so much difficulty in assuring just promotions.

ATTITUDE OF A SUPERVISOR

Because the abilities a supervisor should possess are generally known, I should like, for a moment, to speak about attitudes for I believe these are every bit as important to the success of the supervisor as his abilities.

The first of these is courage. This involves a willingness to assume a calculated risk as well as a wantingness to face difficult personnel situations and to make decisions. The most common complaint one hears from all levels of employees is this: "No one tells me how I am doing; no one helps me work on the things I could be doing better." Sure, it is hard to sit down with some people and explain their inadequacies but identification of such inadequacies must necessarily be the first step in development.

The second of the attitudes is objectivity. We all have, and should have, pride in our ideas. But, the most dependable means of granting recognition is through utilizing the suggestions of others and giving them credit for their ideas. Many supervisors fail to see that management generally respects and rewards the supervisor who is able to elicit the best approach whether it is somebody else's or his own. And this is one of the keys in bringing along a successor.

The third of these attitudes is flexibility. We commonly think of this as an ability which has to do with being able to move from one kind of a problem to another without getting tied up in details, or as an ability to adapt to an unfamiliar situation without losing effectiveness. Here, I shall consider it as being open to the novel and the untried, being receptive to a consideration of the different.

The fourth, and possibly the most important of the attitudes, is humility. I see this expressed as a willingness

to let our deeds speak for themselves but most of all as a desire to want to understand others, about whom we still know so little.

GROWTH OF THE ORGANIZATION

If our concern were only with productivity as measured in the end output of materials, I am certain we could agree quite readily upon some of the means and methods to bring this about. But our concern must go beyond this. We must also be preoccupied with the continuity and growth of the organization. I am using "growth" here in the sense of maturing rather than merely expanding in size. We can achieve this continuity and growth only by working understandingly and developmentally with people. This, of course, posits the acceptance of mistakes and errors, the making of false starts, the delays by repression of behavior. These temporary setbacks are not in vain, however, because as we achieve growth, we also achieve increased productivity. Supervision, then, involves a balancing of objectives although, at times, we may feel that the newest hole in the dike is far beyond our reach.

THE INDUSTRIAL ENGINEER

The extremely varied backgrounds (both educational and work) of Industrial Engineers, and the commonplace of their mobility from organization to organization, subsumes that they function in many different departments. In one of the companies with which we work, Industrial Engineers currently head the warehousing, maintenance, and transportation departments as well as the Industrial Engineering section.

I should hope that the concepts we have discussed here would be valid in their application to all of these positions. It is appropriate to add, however, that there is an additional consideration worthy of scrutiny wherever professional men are supervising other professionals. Where the professional engineer has been carefully selected and where his period of orientation to the new job demonstrates that he possesses the technical abilities of a qualified Industrial Engineer, there is merit in the supervisor recognizing that an administrative hierarchy is necessary but that a professional hierarchy is not. This means that the supervisor will guide and will be objectively critical of the ways in which the new man adapts to the particular needs of the environment but will respect the technical knowledge which the employee brings to the job.

It is pertinent to emphasize that the Industrial Engineer is tapped for supervision only after he has succeeded in a most difficult staff role. The coordinative function in the case of the Industrial Engineer is fully as important as the supervisory function, since his success in the coordinative will emerge only as he exhibits the various abilities an attitudes we have already identified.

As much as any individual, and more than most on the payroll, he is concerned with change. Since the very idea of change is reprehensible to most people, he must be diplomatic and persuasive but still persistent in the recommendations he makes. One of our clients, in selecting Industrial Engineers, deliberately seeks congenial individuals who are quickly able to establish rapport with their associates.

The Industrial Engineer needs to develop a keen sensitivity to timing, knowing just when this idea should be pushed and this suggestion layed down. He achieves certain gains as he credits some people with ideas he originally conceived himself. If he is tremendously aggressive, with a built-in need for prestige and status which seeks outlet in running to management for approval, he will fail to build the bridge of people he needs to support his program. He must be careful that his ill-defined responsibility (in many companies) does not encourage him to venture into areas for which he is not equipped. There is ever-present danger that his success in time studies, for instance, may encourage him to think of himself as an expert in personnel. He needs to be aware of the pulse and tempo of the organization because this will assist him in deciding just how quickly he can achieve certain moves. Because he is so concerned with change and progress he runs the risk of identifying himself with management to the exclusion of identifying himself with those supervisors who will be most affected by the changes.

When the coordinator or staff-man has avoided all of these pitfalls and is actually moved into supervision, he then experiences the most difficult lesson of them all: learning that, although right, he can still be wrong. He finds that he will be misunderstood on many occasions, since he possesses information his subordinates do not have. He finds that if he is to engender respect in his men, he must announce and disseminate decisions as his own even when he is not in full agreement with them. He finds that in order to help people grow and to maintain the continuity of operation, he must hurt the feelings of others, even though he does not do this willfully or deliberately.

And, many times, he discovers that his attempts to develop others or to compensate for subordinates' weaknesses will backfire in terms of engendering additional problems. For instance, in delegating or in encouraging people to think for themselves, he may provide them with what they regard as inadequate information and thus incur additional resentment. Or, again, in trying to push for action he may throw out suggestions which, to the inadequate, suggest finite action. The result is that a procedure or method becomes installed in a fashion which was never intended by the supervisor.

So you still want to be supervisors! Well, if we accept the idea that two-way communication is right and that team efforts is profitable, then we ought to buy the concept that: 1. we must assume a responsibility in actively looking to our own growth; and 2. we should accept the role of assisting the development of our own supervisor

because, believe me, he needs lots of help in what will never be an easy situation.

Leadership for Production

by **MILTON GORDON**

Associate Director, Management Development Center, California Institute of Technology

THE SUBJECT before the group today brings to mind a sequence in the film, "Snowball Conference" which was made by Allen Mogenson. In it, the general manager of the corporation points out to his plant superintendent that today things are not as they used to be. Today you have to lead your men, you can't push them around. To this, the plant superintendent responds, "Okay C. J., I'll lead them, but damn it, they'd better follow." This problem of getting them "to follow" in the most simple, practical, and efficient manner has been the subject of research and study for an extended period of time.

Recently, industry has been going through a "human relations" period. In browsing through our Industrial Relations Library at Caltech, here are but a few of the titles which one may find. "Human Relations," "Human Relations in Industry," "Human Relations in Business," "Human Relations in Administration," "Human Relations for Management," "Human Relations in Small Industries," "Successful Human Relations," "Human Relations in Changing Industry," "Human Relations in Supervision," "Human Relations in Action," "Principles of Human Relations," "Human Relations in Modern Industry," "Human Relations and the Foreman," "Supervisor's Human Relations Library," and "Case Studies in Human Relations."

This is but a small sample of what is available. In spite of this "crusade" we have become suspicious of what all this human relations means and where it has led us. If nothing else, all these books, films, and discussions have certainly made us more conscious of the field of human relations, have made us more humble in our dealing with people, and I am afraid, made us more evasive in attacking some of the basic problems of management that are only indirectly related to human relations.

DEFINING THE PROBLEMS

The problem of leadership for production has both short and long-range implication. There are times when the supervisor can concern himself only with the immediate situation, and must conduct himself accordingly. However, for purposes of our discussion, let us limit ourselves to the over-all qualities of leadership and supervision which would have their greatest impact for a period extending beyond any immediate emergency. There has been extensive investigation to classify the various types of leadership and to determine what overt behavior is representative of each type of leadership. Tannenbaum and Schmidt (10) describe a continuum from "boss-centered leadership" to "subordinate-centered leadership." At one end the boss-centered leader is represented by a manager who makes decisions and announces it, while on the extreme, the subordinate-centered leader is represented by a manager who permits subordinates to function within limits defined by the superior.

Lippitt and White (1) characterize the democratic leader in this manner:

1. He permits all members to discuss policy formation. Encourages the group to make necessary decision.
2. He permits discussions of future as well as present activity. Does not try to keep members in the dark about future plans.
3. He permits members to define their own job situation as much as possible. For example, the defining of the way to accomplish tasks and the division of tasks is left up to the group.
4. He focuses on obtaining objective facts on human problems. Tries to base any necessary praise or discipline upon these objective facts and not upon his personal needs.

Gordon (5) suggests that group-centered leadership is maximized when the members are:

1. Safe from dependence on a formal leader.
2. Are permitted to determine their own goals and skills they intend to use to achieve these goals.
3. Are permitted to define and initiate for themselves any changes within the group.
4. Are not lead by any one individual all the time.
5. Are free to depose their leader (physically or psychologically) whenever they desire.

On the basis of these criteria, we might conclude that there are few democratically lead organizations. We might then very well question why there are so many in the field who recommend such leadership and so few who would follow it.

LIMITATIONS ON RESEARCH

Two basic reasons for the failure to stampede to this type of leadership involve:

1. The difficulty in scientifically evaluating whether such leadership is effective.
2. The absence of *conclusive* evidence to indicate that such leadership works.

In investigating leadership, there are three basic problems at hand:

1. What is the present type of leadership and what kind of leadership are we trying to evaluate? How do we set up a controlled program in which such leadership takes place so that it may be evaluated?
2. Are there any sound techniques for measuring attitude? Do the common attitude surveys which should reflect reaction toward leadership actually do so?
3. How can we effectively measure productivity? Can we come up with measures which will reflect the type of leadership and eliminate all other variables?

It should be pointed out that there are few companies which are willing or can provide good experimental situations. Organizing departments with different types of

leadership and controlling other variables is most difficult. In most situations we are limited to conducting some depth analysis of the type of leadership at hand, and evaluating its effectiveness.

Measuring attitudes is a problem which the social scientists differ on. Although there are many who claim that the verbalizations of individuals are as good a representation of their attitudes as any other measurement, there is a growing trend to minimize this point of view. Those of you who have read the "Hidden Persuaders" know of the great movement to study in depth and thereby analyze the attitudes of the consumer and employee. An example in point is the varied reactions of housewives to the same detergent (they did not know it was the same) when it was contained in different colored boxes.

The classical Hawthorne experiment as a side factor found that the employee commented on the improvement of food in the cafeteria. Those making the study pointed out that the food in the cafeteria hadn't changed, but that the girls had. Another study by Saenger and Gilbert (9) points out that interviews made after passage of New York's State FEPC Law revealed that those who had just made purchases from Negro clerks often verbalized that they objected to Negro clerks and would not make such purchases from them. Their verbalizations were in contradiction to their behavior. Again, are we measuring how people truly feel?

Measuring productivity becomes hazardous because it is extremely difficult to find directly comparable jobs done by groups, who in turn markedly differ in attitude. Also, it is difficult at times to measure certain types of productivity. How, for example, do we objectively measure the productivity of people in engineering, research development, and a variety of other creative fields?

We must conclude then, that any research findings are particularly subject to careful analysis on the basis of experimental design and the ability to measure the factors involved.

RESEARCH FINDINGS

Although there have been a number of studies attempting to analyze the effectiveness of various types of leadership, it is extremely difficult to fit them into a clear-cut interpretation of meaningful pattern. For example, the Michigan Survey Research Center has reported a number of positive findings indicating that "democratic" leadership or "employee-centered" leadership results in higher levels of production. At the same time, Weschler, Kahane, and Tannenbaum (11) give this interpretation.

> One of the most important hypotheses which has been largely substantiated by the Michigan group holds that high productivity is not necessarily a function of job satisfaction or morale.

Herzberg, Mausner, Peterson, and Capwell (7) in summarizing twenty-six studies in this very area, come up with the following findings.

> Fourteen studies show a positive relationship between employee performance and favorable job attitude; nine studies show no relationship while three studies show a negative relationship.

Percentage-wise, this comes to 54 percent positive, 35 percent no relationship, and 11 percent negative relationship. Six months after the publication of this report, Brayfield and Crockett (4) came up with interpretations that are somewhat at variance with those presented in the aforementioned report.

They infer in their review that "there is little evidence in the available literature that employee attitudes . . . bear any symbol . . . or appreciable relationship to performance on the job" (7, p. 113). It should be pointed out that the two sources evaluated different studies and used somewhat different criteria. One group is receptive to suggestive findings while the other group insisted upon statistical significance. Even if we accept the summary of the twenty-six studies, we must certainly agree that there is reason to question whether a 54 percent majority is conclusive.

A look at some of the findings of a few studies may be of value to the individual supervisor in determining how such evidence may be related to his particular organization. Those who have conducted these investigations are very careful to point out that the findings of their particular research are not necessarily applicable to any other organization.

One such study was conducted by the Survey Research Center at the University of Michigan at the Prudential Insurance Company of America (13). They found that first-line supervisors in high production work-groups differ from those in low production groups in that they:

1. Are under less close supervision from their own supervisors.
2. Place direct emphasis on production as the goal.
3. Encourage employee participation in the making of decisions.
4. Are more employee centered.
5. Spend more of their time in supervision and less in straight production work.
6. Have a greater feeling of confidence in their supervisory role.
7. Feel they know where they stand with the company.

The most recently reported study emanating from Michigan (8) concludes that a "Hierarchically controlled" group increased production 25 percent via an ordered cutback in personnel, while a "Participative" group on its own decided to reduce the work group increasing production 20 percent. However, the "Hierarchically controlled" group showed adverse reactions in terms of loyalty, attitudes, interest, and involvement in work.

Viewing the long range picture, Likert comments:

> These results demonstrate that on the average, pressure-oriented threatening, punitive management yields lower productiivty, higher costs, increased absence, and less employee satisfaction than supportive, employee-centered management which uses group methods of supervision coupled with high-performance expectations.

Another interesting study conducted by the same group

at one of the larger utilities indicated a need for more intensive analysis and follow-up of findings. The Survey Research Center conducted a training program in leadership emphasizing the inherent values of a democratic approach.

A measure of pre and post training supervisory performance indicated that the group receiving the training did not substantially improve in their supervisory activities. This, of course, surprised those in charge of the program since reception was very good.

Further analysis indicated that there was within the total group a sub-group that made a significant gain, and a second sub-group which appeared to decrease in its effectiveness. The "gain" group were those who reported back to a superior who himself operated in a "democratic" manner. Those who went back to an "autocratic" leader found that they were confused and somewhat perplexed when a decision had to be reached affecting the kind of leadership they should exercise.

One might conclude that the answer to the problem is that a program should be set up for superiors of these supervisors who are autocratic leaders so that they in turn might change their behavior. We might question whether this is practical. Perhaps a more realistic approach would be to set up a special training program for a select group which would concern itself with how to live and work under an "autocrat."

There is also some evidence to indicate that some dissatisfaction is part of the personality or attitude make-up of the high producer. For example, in one study (12), salesmen who were very disgruntled because of the control which the home office placed upon them turned out to be the highest producers. In another study (3), Linotype operators who were most productive, were those who were dissatisfied with their job, but most liked by their fellow workers. These were individuals who had from eight to thirteen years of experience, who felt confident enough to express dissatisfaction, had a high level of aspiration, and had not resigned themselves to their status as journeymen printers.

What we might actually be finding is that those individuals whom we rate low because of attitude, might actually be our best producers. A study of insurance salesmen (6) reported a high correlation between morale of the salesmen and their productivity as measured by the impressions of their supervisors. However, their productivity was much less than their supervisors realized.

The available studies seem to indicate that there is no one simple answer to the problem of what kind of leadership we should provide. There is evidence to support any of several contentions. What must prevail is a good deal of understanding based on analysis of the individual's situation plus the application of some often-overlooked principles of behavior.

One of the most overlooked fundamentals is that any democratic approach, not only involves participation and the privilege of being heard, but more important, the responsibility of being well informed and logical so that the individual can make his contribution. Where this responsibility is not assumed by individuals, there can be nothing more than a pooling of ignorance.

A good supervisor has the qualities of both being liked and respected. The two will not always go together. At times one must be unpopular and disliked. On the other hand, no supervisor can survive solely on the basis of his being respected for what he knows and can do himself. There are times when supervision can thrive in an atmosphere of freedom. Other times strict discipline is essential.

The experiences of our GI's in the Korean conflict and the falling apart of prisoners under "brain washing" techniques, should point out to us the apparent absence of discipline which seems to be part of our way of life. While the military and industrial situation certainly are not the same, in both there is a common denominator of need for order, control, and carrying out of specified directions.

A PRACTICAL SOLUTION

What appears to be the solution to the question of what kind of leadership is best, perhaps may be found in an answer that to some may be no answer at all.

Argyris (2) describes what he calls "reality-centered leadership." To him it is not a predetermined set of "best ways to influence people." It focuses on the reality in any given situation. We might then question, what are realities in each situation which we must face in determining which kind of leadership will be most effective?

The individual supervisor, his men, his company, and the specific positions which he supervises, all play an important role in reaching such a decision. Each of us most know our own make-up. We must understand whether we can make decisions rapidly and with ease. We must know whether we are able to take pressures, and how we are likely to react under such pressures. We must know whether it is easy for us to give orders, or whether we feel rather humble when requesting others to carry out our demands. Indications are that most executives are not democratically oriented, and therefore, find it difficult to make democratic supervision flourish.

Secondly, we must understand our men. We must know their potentialities, what they know, what they are capable of learning, and in what position we are to provide such learning. We must know their personality patterns also. It is necessary to understand how they function during emergency; whether they possess a lot of drive and energy, or whether they are either unwilling or unable to meet severe demands. We must evaluate their ability to take pressures. Recognizing that all people are alike in many ways, and yet each is different in many more is essential to reaching an understanding of how to supervise individuals.

Thirdly, we must know our organization. It is constantly emphasized that each company has its own per-

sonality. The personality usually stems from a single or a few key executives. Knowing them will help us to understand which type of leadership is most likely to succeed. We must realize that some companies by nature run on an emergency basis. This may be particularly true of those organizations, for instance, which go through a variety of model changes, or are organized to serve emergencies of customers. It also follows that we must be realistic in attempting to bring about any changes within an organization. It is difficult, if not impossible, to bring about basic changes in an individual. Certainly, it must be more difficult to change an organization which is made up of many individuals.

Finally, each supervisor must have not only an understanding of the people, but of the jobs involved. Until he has clearly in his own mind, and has passed on to the minds of his subordinates, the specific responsibilities which ought to be assumed by each individual, there is going to be conflict. Not only must he know the duties and responsibilities of the position, but he must have in mind some levels of performance (standards of performance, if you please) which he knows he has a genuine right to expect.

What this approach appears to call for is a kind of built-in flexibility. This in itself creates the problem of evaluating when one is flexible and when one is inconsistent. It demands that one defines and operates within practical limits. Above all, it points out that there is no pat answer. The supervisor who embarks on a democratic, or autocratic mode of behavior per se will inevitably be trapped. This is the challenge of supervision. Can we assess the situation and demonstrate real leadership in meeting predetermined goals?

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Drive Them or Lead Them

by **MARK E. LUNDIN**

Industrial Relations Manager, Western Division, The Dow Chemical Company, Pittsburg, California

TO DEVELOP a few reference points, let us discuss for a moment the functions of a supervisor. These functions, although presented tersely, cover wide ranges of activity with considerable implication. Nevertheless, in general we would all agree that a supervisor at any level has two elemental functions. The first is that of utilizing the mental or physical efforts of those employees assigned to him to accomplish a defined task. The second is that of exercising some know-how and problem-solving activity as defined by the area in which he works. We could probably readily agree that the emphasis will shift as we ascend the scale of supervision from the first line foreman. On the surface we have a simple task. Select workers to do the job. Name a supervisor. Get the job done. It may be simpler than we make it but at best it is complex.

Why is it complex? One of the reasons is because we immediately assume in many instances, as our topic indicates, that we must either: 1. drive them; or 2. lead them. The choice; 1. connotes to us as individuals that it is the choice of an absolute autocrat; or on the other hand 2. lead them, the choice of a patient, permissive democrat. As you can already see, one of the problems is that we as managers, and certainly as individuals, assume that one of the choices is absolutely correct.

DRIVE THEM?

So that we might explore this, what are the usual assumptions? Drive them. Does this not imply that the supervisor is always inherently correct? Upon inspection with reason, we know this is not the case. It would deny the presence of human fallibility. By some rare stroke of nature, the supervisor would have to be omnipotent on the one hand, and omniscient on the other. As professional and management personnel we are forced to reject this, since we can be reasonably sure this is not

the case with our peers or supervisors.

Nevertheless, there is a great tendency, however irrational it may be, to practice this approach. Possibly not only among the staff and management groups but in a larger number of instances in the first line supervision of production employees. Why? Probably for many reasons. From a number of observations the most likely one is the basic nature of the work and relative bargaining power of the individual.

A number of companies put a large amount of effort in their Industrial Relations Departments, and for that matter Industrial Engineering Departments developing data to *prove,* even in doubtful cases, that its foremen were correct in their action. Would not this time and effort be better spent in preventive work? This principle is well accepted in any effective and efficient Maintenance Department.

To return to the "drive them" philosophy, as a generalization, when this is accepted a corollary is superimposed, reading something like this: Foremen are important members of management.

No one would disagree, but in execution many times an attitude and atmosphere is created by implication that says this:

> As a foreman, you are intellectually, economically and socially different from those you supervise.

In any given segment of an organization there is a degree of truth in that statement. But, explore in your mind the organizations with which you are familiar. In general, as an individual, is not the supervisor in these terms more like those he supervises than, for example, the supervisors two levels above him on the organization chart?

Why make an issue of this? From personal observations this is of considerable significance—certainly at the lower levels of supervision. The management, in attempting to create stature and status, really isolates the foreman as an individual. He is something aside from the worker. Yet, on the other hand, he is not fully accepted by other members of the management staff. Isolation contributes largely to insecurity, by definition.

How does this arise? One of the main contributors is that in terms of social contacts and social and economic acceptance, there is a disparity, a barrier in educational background, which of course influences wants, needs and goals. In other instances there is an *intellectual* differentiation. Of more importance probably, there may be a disparity in environmental background that is a contributor. All are interrelated in terms of behavior. How do differences arise within the organization itself? For example, compare the first level foreman with his problems of daily scheduling and executing work, as against his supervisor who is concerned with long-range programs and projects. Certainly, the first level foreman's background and experience, with the exception of limited areas, do not lend themselves toward the formulation of a long-term, long-range program or project.

For a rapid summary, the "drive them" approach as a philosophy apparently leads to inefficiency, and ineffectiveness, since it is based upon "right by might," "virtue by assignment," or call it what you will, which we must agree is fallacious in fact. Also, a usual corollary to it may isolate the first line supervisor as an individual.

Because the supervisor is required to divorce himself totally from his workers, on the one hand, and on the other for the reasons indicated, cannot really become a part of another social and economic group, he is divorced from all. This may well result in a feeling of isolation and futility on his part. Or he may take the most non-productive escape route: that of, in a subrosa fashion, joining in a conspiracy against the management with those people whom he supervises. Why the term conspiracy? Actually, it is a conspiracy when the supervisor resorts to the tactic that we all know as "passing the buck"; the nonacceptance or responsibility or accountability. Either of the two alternatives is ineffective from the viewpoint of getting the job done, and should be rejected. Furthermore, if one has any belief in the rights and dignity of man, this alone is more than adequate reason for rejection.

LEAD THEM?

The "lead them" approach, as a cliche implying "Participation" as the major effort on the part of the supervisor, also has some serious problems.

From personal observation and experience three of these drawbacks merit serious consideration:

1. The situation may not involve any degree of choice.
2. The individual employee may not have the knowledge or background to be an effective participant.
3. Are we sure that all want to participate on the basis that is implied in democratic supervision?

Do not necessarily conclude that it was said that people do not want to participate. It was said "on the basis of democratic supervision." What are some of the implications? In the first place, by definition, it is generally group participation. Therefore, is it not mandatory that the individual be capable of and enjoy working as a member of a group. There are a number of extremely effective people who are unable to do this. From personal observations, their reasons are quite understandable and legitimate. Therefore, the democratic approach is hampered in its functioning because of the lack of effective participation by all in the group.

For example, in group meetings much time, effort, and talk may be wasted. Some members of the group may not wish to present differing views to those of their colleagues. Others may not want to labor a point with their supervisor. As a result, talk, talk, talk, and little more, other than possibly frustration and some feelings of insecurity. One clue in this area would be that a fair number of us cannot accept a frontal attack on our ideas. Sec-

ondly, some of us do not want the implied responsibility of being co-participants. There are some others of us who really much prefer to be told, not necessarily in detailed specific terms but in general terms, what is wanted. Then we can go about executing the job in a manner which we know and with which we are comfortable.

Of course, the immediate response on the part of an avid proponent of the democratic supervisory method would be that *well-selected* people do not have these inabilities. This would circumvent the problem, at least at the onset. As a person who has worked in the field of employment for a fair period of time, this drastically limits the number of people who might be selected. The effect in a large number of instances would be to price yourself out of the market.

There is a rather disturbing, or better said, devastating corollary that goes along with democratic supervision as it is many times practiced. It is self-control to the point of almost blind conformance. This may really be almost necessary since for some of the reasons discussed much of management activity implies authority. This is the antithesis of democracy. Yet, as a philosophy it must be practiced. The denominator then becomes conformance.

Where are we then? This probably is the most unproductive of all situations. It has neither the clarity of approach and directiveness of the truly autocratic nor expression of thought and understanding found in a democratic situation. Naturally this is most serious in administrative, professional and executive areas of work since it implies status quo.

If we assume that the "drive them" approach of an autocratic leader is ineffective, then how is it that we can think of good examples of autocratic leaders who are extremely effective? The work is well planned, the workers are well trained. The quality and quantity of production is of first order. Morale is extremely high.

The individual who tends toward the democratic philosophy feels that inherently this must be a fallacy. However, we must recognize that it *is* possible to supervise a group by these methods, accomplish the work that is to be done and have a group with very high productivity and morale. The critic would pose that this is inconsistent, you cannot have high morale and at the same time have autocratic supervision. True, it is much more difficult to do than with other alternatives, but nevertheless it *can* be done. Why? Probably because the people do reach their goals, they know that they are well trained, secure, backed up to the hilt, effective, and, as a result, have high morale. We many times overlook the satisfaction that comes as a result or pride in workmanship or craftmanship as against the satisfaction derived by participation and self-expression.

What can happen if we require this able autocrat to become a democratic supervisor? From personal knowledge, it is tragic. The individual who could plan and execute a very effective program became so involved in becoming a democratic supervisor and was so uncomfortable in this role that his meticulous planning and morale were totally missing. What has happened to the group? They no longer know what to expect. Before the change they knew when he would growl and when he would bark. Now, they have little or no frame of reference. As a result, the effectiveness of his workers was destroyed. There was on one hand an effective group, productive with high morale; and on the other, an ineffective group with low morale and a very unhappy supervisor.

Again the critic would petition, "One should not employ an individual of that nature." But, what more can we ask from a supervisor than high productivity and high morale?

SUMMARY

The case may be summarized in this fashion. Why do we have supervisors? The answer is to lead people to desired goals. What are the tests? They are the traditional ones of quality, quantity, cost, and morale. If these are acceptable goals then it is incumbent that we discard or at least de-emphasize the approach of "stock phrases," to list a few:

Communications are the most important function of the supervisor.

The management must represent a united front against the Union.

It is incumbent that all employees participate in problems of mutual interest.

The innate ability of all people offers much to the solution of work-place problems.

The first line supervisor as a representative of management must be assured the company is behind him.

All of this, to varying degrees is true. Yet, the inherent trap is in accepting them as axioms. The problem of leading calls for tailoring the aproach and decision to fill the need to achieve productivity and morale rather than imposing an assumed philosophy.

Industrial Engineer

Retail chain organization has opportunity for Industrial Engineer in management position on warehouse supervisory staff. Interest and/or experience desired in scheduling and flow of orders and shipments, fixture and floor plan layout, and systems planning and evaluation. Age to 35, salary open. Company offers complete welfare benefit program as well as advancement opportunities. Relocate to Cleveland, Ohio. Give details in letter concerning past experience, earnings, and pertinent personal information. Interview will be arranged. Box V.

Motivating Engineers

by **ROBERT S. BELL**

President, Packard-Bell Electronics Corporation, Los Angeles

WHEN Packard Bell was founded in 1926, engineers were plentiful, or perhaps more correctly, the need was limited. It was under these circumstances that H. A. Bell, the founder and present chairman of the board of Packard Bell, instituted what has proved to be a far-sighted and stimulating creed for employee motivation. It is this creed, as it has been empirically developed and as it applies specifically to engineers, that could be used as a powerful incentive for growth and a source of loyal support from those who comprise the might of the electronics industry. Briefly, the creed is as follows:

1. Remain compact, regardless of size.
2. Work in small groups where the lack of size will focus attention upon the individual so that his talent, or lack of it, can be recognized.
3. Encourage talent by "from the ranks" promotions.
4. Demonstrate management strength by delegating authority as well as responsibility.
5. Urge civic and professional society activity and insist upon personal responsibility and loyalty to company and supervisor.
6. Develop enthusiasm for joint effort and reward sharing the load with sharing the profits.

POLICY NUMBER ONE

Remain compact, regardless of size. Back when the twenties were roaring toward fiasco and the radio industry was a pup, it was easy to remain compact. Packard Bell, like other struggling beginners, operated as a family business because that's what it was. Today, after thirty years of growing from a garage operation to a multi-million dollar institution with four autonomous divisions and two affiliates, it's still a family operation. The only difference is that the family now has some 2,000 working members and ownership is vested in over 4,000 stockholders.

Much has been said and written about so-called "business families." Often the family relationship idea is a figment of management's imagination with the only paternal impulse demonstrated at the top, chiefly at Christmas time, with very little filial acknowledgement from the ranks.

Every father knows that respect for parenthood is a reward, not an obligation. Likewise, respect for management, in a business family sense, is never inherent. It must be earned. No one has all the answers to this rather nebulous problem, but there are a few things we do to make the working atmosphere more comfortable, comradely and constructive. Here are some "for instances."

To be comfortable, shirt sleeves are the uniform of the day, every day, from top executives down through supervisory levels. To be comradely, we recognize that everyone has a first name and is addressed by it. To be constructive, we are aware that communication between levels and individuals presents a complex problem in an organization of our size; yet we have to realize that efficiency and its blood brother, economy, are based on complete knowledge and understanding of any given situation.

Lack of communication, lack of comprehension of what the other man is thinking and planning and doing can cause a major disaster resulting from suspicion, ignorance, and conflict: personality-wise and policy-wise. To achieve harmony, we have established certain means of communication, written and spoken, so that no one is ever in doubt about what is currently going on, what has been done and what is planned for the future.

Our written means of communication include several types of internal publications, geared to the interests of different levels. In addition to a handsome monthly house organ called "The Printed Circuit" which is issued to all the employees of the company, and there is a "Management News Letter," circulated among those on a supervisory plane. Bulletin boards are used extensively by anyone with something worthwhile to communicate. Copies of news releases are distributed so that all may know we have interesting information to share with the world before they read it in the press. Proofs of our advertisements are posted on the bulletin boards and all new Packard Bell publications receive wide distribution within the plant.

In addition to the written report, we place much emphasis on the spoken word in the informal "bull session" or "brainstorming" type of staff meetings, conducted on diverse levels. Once a week four or five new employees (from engineers to assembly line workers) meet with several older ones and the management staff at a "get acquainted" luncheon. Anything and everything is discussed except business. They leave the luncheon with a pretty good idea of what makes the other person tick and the next time they meet in line of duty, they have background material to draw on.

Staff discussions are held from time to time among those on various supervisory stages within each division to explore immediate plans and iron out knots and kinks.

Once a month a meeting of supervisors is conducted by each division of the company, at which time the current status of business is spelled out in detail. These people

then go back to their groups and spread the word.

At the end of every six months the president's report is delivered at a dinner meeting to all supervisors and senior engineers of all divisions. This, too, is a cold turkey exposé. Profits, prospects and forecasts are blueprinted for these men, who have come to realize that everyone present is a partner in the business as well as a stockholder. Each is as important and as necessary as anyone else. He belongs to the family in fact, not in name only, and shares in it mentally, spiritually and financially. A well-informed employee is a responsible and authoritative employee.

POLICY NUMBER TWO

Work in groups to focus attention upon the individual. Packard Bell's transition from an established commercial industry to a balanced commercial-military industry would have encountered far more severe growing pains if it had not been for this policy of group effort and individual recognition. When brainpower is your chief raw material, and it's scarce, a little often has to go a long way. You need an "engineer stretcher" and there is such a device, built-in. It's called "ambition."

Fundamentally, the motivating of engineers to highest effort is a matter of providing scope and encouragement for personal and professional growth while guaranteeing a firm foundation of financial security. They want a job worth doing, a challenge for their talents. They want to know that the place in which they work is large enough and far-sighted enough to provide growing room, yet compact and intimate enough to make recognition possible in the shortest conceivable time.

Compact and intimate does not refer to the size of a company but to the size of an engineer's working environment. In a group of three, six, even twelve engineers, bolstered by collateral services such as scheduling and budgeting, the individual can make his maximum contribution. He can climb rapidly from number twelve or six in a group to number one in a group of his own. The burden of proof is fairly upon him, for his ability constantly is under review. That's all a good engineer asks. Ability will take care of the rest, because scientific achievement for its own sake is a strong motivating factor and, when coupled with acknowledgement of achievement, it is an irresistible force.

POLICY NUMBER THREE

Encourage talent by "from the ranks" promotions. Americans are a peculiar clan. They take exceptional pride in those who have "made it the hard way," pointing out the opportunities that exist for each individual to become a self-made success. Success can mean various things to various people. To one it may be accumulating a half interest in Fort Knox, at any cost. To another it may mean the quiet satisfaction of a job well done; a perplexing and intricate problem intelligently solved; or the acceptance by the world of a contribution, large or small, to mankind's well-being.

There are other interpretations but the one word that correlates them is "recognition." This may be by the accretion of gold (which is recognition in many quarters), or glory (whether a Nobel prize or a pat on the back from a respected source), depending on one's own sense of values. Regardless of how the recognition arrives, in the form of fabulous sums of money, plaques and trophies of rare and precious metals, scrolls of sheepskin, a promotion to a better position, the tangible, physical award, while perhaps valued, is not of greatest importance.

The significant fact is that our exertions, our accomplishments, are recognized, thereby enhancing our mode of life and enriching it by encouragement and stimulation to greater efforts. How stifling, how frustrating to expend time, pains, zealous and prolonged effort, only to have our attainments ignored!

Recognizing this as a prime motivating factor, psychologically, in any individual, we have a firm policy of "from the ranks" promotion and advancement. There is practically no limit to our endeavors to encourage and reward talent. It is not unknown to create advanced positions in order to obtain maximum mileage out of a concept, a dream, a plan, an idea. What better incentive can a man have than the security of a rewarding, responsible position with no dead ends, but only a long, open highway upon which to drive his fertile imagination? Here there are no speed limits or traps, no hindering obstacles, no obstruction of view, just broad vistas of unlimited opportunity for professional expansion and significant personal growth.

POLICY NUMBER FOUR

Demonstrate management strength by delegating authority with responsibility. A recent issue of *Fortune* magazine refers to the men who manage the electronics industry as "a new breed of executives: the scientist-engineer turned businessman." The article goes on to say:

> Electronics had no ready pool of talent to draw from when it began to expand rapidly in World War II. During that period it was manned by the bright engineering and scientific graduates of the late 1930s. These men are in their forties today, surrounded by the youngsters who have come out of the universities in the last ten years.

Those 40 to 50 year old engineers turned businessmen are, in fact, the pivots of our industry. Engineering management is, and should be, recruited from the ranks of engineers. Our Vice President in Charge of the Technical Products Division is a registered professional engineer with two engineering degrees; the Director of Engineering is an engineer with a doctorate in physics. Their twenty-odd years of broad experience, from laboratory work up the ladder to top executive positions, gives them an understanding not only of engineering problems but of engineers themselves. They know, because they learned it

the hard way, that responsibility without authority leads to discouragement and frustration. It's a long road from one responsibility to a higher one when authority rests solely in an ivory tower, removed by space and time from the place and moment of decision. Mental gray hairs come at an early age to those blessed with the authority, not only to think for themselves, but to decide and act accordingly.

We have mentioned previously in this section that a new specialty is rearing its head within the already highly-specialized engineering profession. The singular expert whose talents are beginning to be in demand is the engineer with management, administrative and/or business training. The need for this is obvious. The engineer, in order to be fully acquainted with his project, should know the "how come" of the "before" and the "what for" of the "after." He should understand something of business methods, contract negotiation and administration, cost accounting, and the gentle art of dealing happily with clients on the outside and supervisors and other employees on the inside.

Unfortunately, not every engineer is a charmer nor a potential business tycoon, but we assume the potential in all our people. To this end, we are currently planning a program in management training which, we expect, will not necessarily explode each engineer into a superlative salesman, public relations practitioner, or father to all the workers on the assembly line, but will discover and exploit the managerial qualities inherent in most of them. This on-the-job training will have a many-fold payoff in that we can expect increased awareness of business and administrative difficulties aside from the familiar technical problems. Following naturally will come an enhanced sympathy or empathy along chains of command in all directions and on all levels, with resulting understanding, cooperation and team spirit, all redounding to the benefit of client, company and employee.

POLICY NUMBER FIVE

Urge civic and professional society activity and insist upon personal responsibility and loyalty to company and supervisor. Through the ages, the market place, the bazaar, the town square, were the centers of exchange of news and views, the trading of tangibles and thoughts, the sharing of materials and information. As urban living expanded and greater portions of the unpopulated areas of the world were colonized and settled, the easy informality of face-to-face conversation with people whose interests were mutually shared became more difficult. Increased correspondence throughout remote sections of the earth resulted and, consequently, the newspaper business throve and expanded. The need for specialized journals dealing with specific areas of thought became apparent and, as a natural adjunct, the necessity for clearing houses for the divergent theses, hypotheses, opinions and deductions of the people involved in any particular branch of science or commerce. Since the days the guilds were first founded, artisans had banded together for, among other reasons, the exchange of thoughts on how to accomplish a task in a more efficient manner, with a superior result, and so the professional societies were born.

A man may have need for a particular piece of information. So far it has not appeared in the literature. His own research and experimentation have not exposed this one small, elusive fact which may permit him to make a world-shaking contribution. Another man, on some other tangent, with a totally different objective in view, may have uncovered this very piece of, *to him*, useless information. Bring them together, and incalculable good may be produced. Thus the professional societies serve as the meeting place, the arena, the forum, catalyst, if you will, for an exchange of thoughts, dreams, ideas and concepts.

The symposiums, conferences and conventions of today serve the same purpose as the market places and bazaars of yesteryear. Here men meet, albeit not to barter merchandise. Their stock in trade is the product of minds. Here they can examine the latest information and results of experiments, and present to each other the missing pieces to complete some precedent-shattering scientific jigsaw puzzle.

We encourage our people to participate in the activities of their professional societies. The man who is most knowledgeable of the latest developments in his own field is the most desirable and valuable to any company. This is particularly true in our industry, where so much well-deserved stress is placed on research and development, and up-to-the-minute awareness of the latest contributions to the state of the art may make all the difference in the world where the success or failure of a project is concerned.

Employees are also urged to participate in civic and community functions because a happy employee is, of necessity, a well-rounded employee and good citizenship is vital to an individual's good character. There is also the not small matter of public relations, since an employee who is a credit to the community in which he lives, by the same token accrues credit to the company for which he works.

Active membership in professional organizations is as important to an engineer as his job and his home. Allegiance to family, company and supervisor reflects a man's character. Allegiance to professional or civic organizations reflects his stature.

In the same manner that chain reactions are set off by the interchange of ideas, so does loyalty to supervisor and company spread when you have an interchange of loyalties. Loyalty must go from bottom to top and be returned from top to bottom to exist as a practical working idea.

POLICY NUMBER SIX

Develop enthusiasm for joint effort and reward sharing

the load with a sharing of profits. "No man is an iland intire of it salfe. . . ," wrote John Donne a long time ago. It pertained then and pertains now. The day of the hermit is over and the time of the team is here. The term "project team" is in common use in our industry and it means just exactly that, a *group* of people, all contributing their special scholarship, experience, talents and efforts to the successful conclusion of an assignment.

We have discussed the group system as it affects the professional growth of an individual. It has an equally important effect upon his personal growth. Team effort in business is as vital as it is on the baseball diamond or football field. Harmony at the creative level, with several minds collaborating toward a common goal, cannot operate in an atmosphere of suspicion, jealousy or temperament. Conversely, an engineer cleanses himself of these growth-retarding faults when his enthusiasm for another's contribution equals his pride in his own.

There is very little management can do to create this environment of mutual admiration and team spirit except to practice it, encourage it and reward it, and speaking of rewards, we have left a vital point for the very last: the matter of financial reward for a job well and truly accomplished.

We reward sharing the load with a share of the profits. Ten percent of annual net earnings *before* taxes is set aside for distribution in the form of profit sharing, which is invested in company stock, so that when the engineer working beside you comes up with a lulu of an idea, you're not about to be unhappy. That idea becomes yours as much as his because it belongs to the company and the company, to whatever extent you desire and deserve, belongs to you.

Management of New Products[1]

by **RALPH W. JONES**
Partner, Booz, Allen and Hamilton

LONG lists can be constructed for the importance of new products, but in business strategy most of these boil down under three major headings:

A major contributor to company growth
A primary influence on profit performance
A key factor in business planning

Recent business history demonstrates that "growth" industries (drugs, chemicals, electrical machinery and electronics) have been heavily "new product" oriented, as illustrated by R&D expenditures, which are one measure of new product effort. Within all industries, most growth companies attribute a large percentage of their sales and profitability to their new products. Several dozen well-known company histories have been documented as specific examples. It is about "par" to have around 50% of sales in products that are new to the company since the War.

Analysis of many industries and many companies leads to the conclusion that a company can't do much better than its products allow in the long run. It is difficult to make a living selling something people don't want to buy.

PROFIT MARGINS

New products have a characteristic pattern to their sales volume and profit margin curves as shown in Figure 1, but these two curves are different. The time scale varies by product and industry (as short as 4 or 5 years in drugs) but every product must expect to be preempted eventually by another product. Long before this occurs, production will catch up even with growing demand, and the product degenerates into profitless price competition, as the typical profit margin curve shows. This means that as a business strategy, a company must plan to run ahead of price competition by differentiating its products and introducing new products that can command better margins.

Business success is governed not only by what you do, but by what others do. Therefore, throughout history, the underlying secret of business success has been to be in the right business at the right time. This strategy is expressed by the selection and development of company products. Over-all profit margins can be sustained only by a continuing flow of new products, not only to replace sales volume, but also to bolster shrinking profit margins.

BUSINESS PLANNING

Company plans must begin with the product plans. To project sales, costs, capital, facility and personnel needs

[1] Prepared by the Management Research Department of Booz, Allen and Hamilton, based upon the following sources: 1. Records of work with over 1700 clients, including 300 reports where many ideas have been tried and confirmed; 2. Leadership in 15 national conferences and seminars, which provided a means for sampling broad groups of opinions beyond the scope of formal interviews, and a testing of early conclusions in extended discussions; 3. Public and private literature; 4. Special studies of 40 companies (mostly large, nationally known, with substantial experience) that have been successful in developing and launching new products; 5. Information collected from 400 manufacturers through visits, personal interviews, conferences, mail and literature.

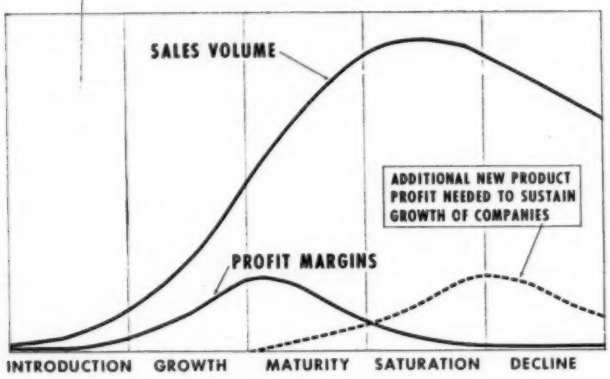

FIG. 1. The Basic Life Cycle of New Products.

without clear product plans is indeed a hollow activity. The growth plans of a company are at the core of management interests. New products are a major factor in the growth plans of companies today. The impact of new products is clear even in the short-term plans (1955-1959) as illustrated in Figure 2. The length of the bars show the dollars of sales growth expected in ten industries. The shaded part of these bars is the share of this growth expected from new products, ranging from 30 to 80%.

GROWTH ACTIVITY

In the face of these facts, it is no wonder, then, that management is concentrating such heavy attention on new products. Recognition of the importance of new products is reflected in the rising rate of new product activity.

Almost all companies these days say they are working on new products or confess that they wish they were.

R&D expenditures are rising at a rate of 10% per year—over 20% recently.

Corporate acquisitions, in large part an expression of the drive for new products, are reaching progressively new highs—an estimated 100 a month or more being consummated.

An increasing number of companies recently have established special new product or product planning departments—a positive indication of managements' desire to accelerate or improve their new product programs.

We now know over 65 of these departments. We find about ⅔ of these less than two years old. Few of these new product directors, managers, or vice presidents, know each other. The movement toward more definitive organization of the new product function has been a spontaneous response to internal pressures generated in many different places.

BASIC MANAGEMENT CHALLENGES

New products breed problems by their inherent nature. Hundreds have been listed, any or all of which must be met for new product success. These can be summarized under three major headings as basic challenges to management:

The uncertainty of new product results. Although a comprehensive, definitive and conclusive survey has yet to be made, all studies point to the same conclusions: 1. New products are more likely to fail than to succeed; 2. The companies that can least afford it have the highest failure rate.

The shortage of scientific manpower. Scientific manpower can be increased in total only slowly. Immediate relief can only come in better utilization of existing manpower. Relatively few companies have recognized the manpower waste and morale damage implicit in such a high rate of commercial failures for completed development projects.

The difficulty of organizing and controlling the new product process. Interviews with successful companies with good new product records (the forty we selected for special study have five-year sales growth twice the national average) tends to isolate the most stubborn problems. These proved to be management problems of organization, operations, objectives, and evaluation. These problems center in human rather than technical problems. These findings are in line with our own experience in a wide variety of companies.

Seminar attendance, requests for literature and counts of published articles all show burgeoning evidence of management desire for more knowledge on how to better manage their new product activities. We see it in our own inquiries. The needs of our own clients, in fact, largely led us toward organizing our own New Product Planning staff and selecting this area as a major management research project.

A PROGRAM FOR EVOLUTION

"New product evolution" is a phrase we have had to coin, because management language has not had a word to describe this process, in which development is only one stage and in which R&D is only one department. We find this phrase being adopted and it may come into wider use.

After examining hundreds of experiences, we are convinced that there is a basic approach to new product evolution that is sound for any kind of company in any industry. It is clear, of course, that any pattern must be tailored to meet the unique characteristics of each com-

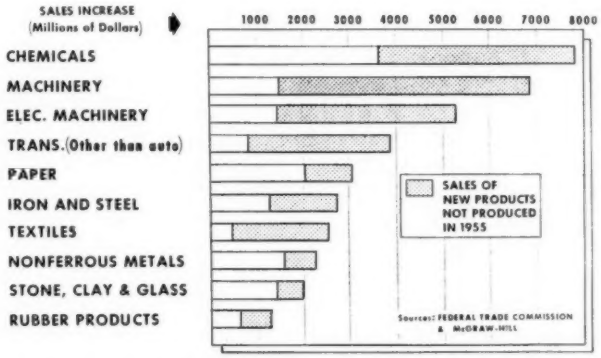

FIG. 2. Contribution of New Products to Sales Growth Expected 1955-1959, by Industry.

pany. However, this tailoring can be most effective when working from an established set of proven principles. The recommended approach and principles are based on actual practices, bridged and combined with our own experience and judgment, which has included the creation and installation of such working programs in a number of companies. We by no means intend to represent here a simple tally of majority practice. The truth is that "majority" practice is rarely "best" practice, as might be suspected from new product casualty rates. Some of the major points actually are overlooked by *most* companies.

Our study has been directed purposely toward an *unrepresentative* sample to begin with; i.e., companies with high reputation and good records on new products. We found many principles in common between them, despite the range of industries and sizes represented. But we also found a number of common problems, and our recommendation is based then on the practices of the relatively few that have successfully bridged these problem areas.

NEW PRODUCTS DEFINED

The medium of business conduct is its products, and thus business strategy is fundamentally product planning. When you select and develop a product you are deciding what kind of business you are going to be; your customers, competitors, suppliers, facilities and skills, and the socio-economic environment that will form the perimeter of your opportunity for success.

Thus, product decisions are so fundamental that they must be, in the final analysis, a top management decision. Viewed in this perspective, a "product" is "business" and requires multi-functional decisions and actions by all major organization components of a company. The two principal dimensions of the product are "technology" (what and how to make) and "markets" (who and how to sell). Products then can be "new" in either or both of these dimensions. "New," for purposes of organization and control, means "new to the company."

Products may have many degrees of newness. This continuing spectrum, however, usually is broken arbitrarily into categories of "improved" or "new." At some point the product becomes so "new" to the company that this means, by definition, that the company has had no experience with the technology, or the market, or both. This is the basic problem of true "diversification." The two-dimensional combination means that two major groups of people, R&D and Sales, must cooperate on a project, which either or both may not know much about. This is the inherent nature of new products. The problems are built-in; they cannot be avoided: they must be overcome.

STAGES OF EVOLUTION

Having established two dimensions of a product, we can now introduce the third dimension of a new product: time. We call it "Product Evolution," the complete process involved from the setting of "company objectives" through ultimate "product success."

To plan and control this complex process with effectiveness requires that it be broken down into segments. When the major points of management decision are charted, the evolution of a product breaks down into a series of definitive stages. After studying dozens of companies and case histories, six fairly clear stages emerge:

Exploration—the search for product ideas to meet company objectives.

Screening—a quick analysis to determine which ideas are pertinent, and should be given careful investigation.

Specifications—the expansion of the idea, through creative analysis, into the concrete business recommendation of the product's features and its program.

Development—turning the idea-on-paper into a product-in-hand, producible and demonstrable.

Testing—the commercial experiments necessary to verification of earlier business judgments.

Commercialization—launching the product in full-scale production and sale, committing the company's reputation and resources.

The stages are usually called by different names appropriate to each company's industry. They may be combined or subdivided. However, this six stage pattern represents the basic management process before company, industry, organization or product variations are introduced. Each of the stages involves three steps. It should be kept in mind that the following listing is only a bare outline. It does not include the "how-to-do-it" that spells the difference between success or failure of the program.

Exploration

1. Determine the product fields of primary interest to the company.
2. Establish a program for planned idea generation.
3. Collect ideas through an organized network.

Screening

1. Expand each idea into a full product concept.
2. Collect facts and opinions, which are quickly available, bearing on the product idea as a business proposition.
3. Appraise each idea for its potential values to the company.

Specifications

1. Appoint persons responsible for further study of each idea.
2. Determine the desirable market features for this product and its feasibility.
3. Develop specifications and establish a definite program for this product.

Development

1. Establish development projects for each product.
2. Build product to designated or revised specifications.
3. Complete laboratory evaluation, and release for testing.

Testing

1. Plan commercial experiments necessary to test and verify earlier judgments of the product.
2. Conduct "in-use," production, and market testing.
3. Make final product decision; freeze design.

Commercialization

1. Complete final plans for production and marketing.

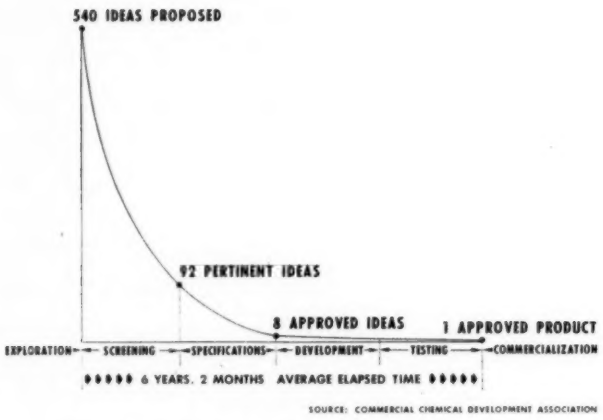

FIG. 3. Mortality of New Product Ideas, from Twenty Chemical Companies, During 1955.

2. Initiate coordinated production and selling programs.
3. Check results. Make necessary improvements in product, manufacturing, or sales.

CHALLENGE OF SELECTION

From the management point of view, this process is the game of "product selection." Product ideas can be sorted against two grids; risk vs. payout. There are more high-risk than low-risk products, and there are more with low-payout than high-payout.

Companies should seek, literally, those rare ideas that are both low risk and high payout.

A characteristic of this game is the progressive rejection of ideas by stage. Figure 3, for example, is the survival rate curve for industrial chemical ideas. You might say that, like a poker game, you ante a lot of times before you develop a hand you are willing to run clear through to a final showdown.

As good a screening job as is represented here, we still see seven out of eight development projects (which run $150,000 to $500,000 or more each in this business) never reach the full commercial stage. This gives us a clue on what might be happening to some of our scientific manpower. A large share, by definition in commercial terms, is being wasted.

Another characteristic of this game is that each stage is progressivly more expensive; or, like the poker game we were talking about, each card drawn costs more than the one before it.

For example, in special process machinery, the last two stages for a new product cost twice as much as the first four stages. This example is by no means as steep as the curve for many other businesses, such as high volume consumer goods where you have to almost "buy into the market."

In this game, like stud poker, the sure way to go broke is to string along for three or four cards on each hand. You get a lot of action, but you dissipate your resources. When you do finally get those aces back-to-back, you can't play it for what it's worth.

This job of evaluation is a big one in most companies, and requires time and an organized program to stay on top and do it right.

In our survey we found companies screening from 250 to 1,000 ideas each year; typical examples are shown below:

Electronics Manufacturer Radio, TV, Communications Equipment	1000
Food Company	900
Special Purpose Machinery Manufacturer	500
Electronics Manufacturer Industrial & Defense Products	500
Container Manufacturer	250
Diversified Metal Products Company	250

One final point. A company must depend largely on itself to create or to get good ideas. Rarely will the independent outside inventor dump a fortune in your lap. It has happened, but companies are finding it rarely worth the time, energy and legal risk.

CONCLUSIONS ON NEW PRODUCT EVOLUTION

Summarizing, then, in light of what is now known, attention should be focused on the first three stages, because this is the area for major improvement in most companies. This is true because:

In the commercialization stage failures should occur rarely, in well-managed and adequately financed companies, because successful companies know pretty well how to produce and sell. In such companies, failure usually traces to an earlier stage and reflects weakness in the product concept itself. The product either does not work like it was supposed to or it turns out people don't want to buy it.

The testing stage is the place to experience these failures. Still, too many products are killed in this stage, after development, for nontechnical reasons that could have as easily been anticipated before development (if given the same thought at that earlier time).

As for the development stage, experienced companies in R&D say, in effect, "Our boys can develop anything. Show me enough sales and enough profit, and we'll spend the necessary time and money to develop it." Most *development* work, after all, should, and does take place within technology fairly well understood at the outset.

So we focus on the stages where we determine "what should be developed." It takes just as long to develop a million-dollar bust as a ten-million-dollar bell-ringer. There are plenty of problems to solve in the world. The secret of success is to be working on the most useful ones.

COMPANY ACQUISITION

There are two methods for getting new products. The main stream is internal development, since someone must do this before the other can occur. But, a company may also acquire new products through corporate merger, in whole or in part. Almost every company acquisition brings a new product along, whether you want it or not. Analysis of over 2,000 mergers in a recent 54-month period of time indicates that "new product" objectives are met in at least half the cases. Our orientation here is toward those com-

pany acquisitions that are promoted by the acquiring company for the purpose of getting into a new business, that is, a new product. Recognizing that this subject deserves a presentation in itself, the treatment here will be brief.

STAGES IN ACQUISITION

When company acquisition, through merger in whole or part, is approached from the perspective of new products, the stages are roughly parallel to those of product evolution:

Exploration embraces the program of getting suggestions of companies to acquire.

Screening is a quick consideration to pick out those of greatest interest.

Investigation includes all possible fact-gathering and consideration short of actual contact, and also includes the development of a rough proposal.

Proposition begins with the first direct contact with principles and then develops the nature and extent of mutual interest.

Negotiation is what this contact, if successful, turns into in time; carrying through full-scale business surveys and terminating with a legal agreement.

Integration is the process of making the legal combination into an effective, operating business combination, in fact.

This last stage takes a long time, and it is a time of major grief in many companies. A large number of acquisitions have proved unhappy. (Considerable "de-acquisition" is probably on the way.) The problems that emerge in the final stage usually have their roots in the earlier stages, where something did not get done that should have been.

Supervising an active program for acquisition is a big job, too.

The number of suggested acquisitions considered by active companies ranges from 100 to 1000 per year.

The record we know of (in a company that acquired 20 others in about 2 years) was screening 57 companies *per week* at the peak of its program.

Heavy work levels cannot be avoided because acquisition ideas have their mortality by stage, too, which almost requires that this be organized and programmed as a major job for one or more people.

The experience of one company, in a two and one half year acquisition program, showed over 100 company ideas had to be turned up for one acquisition to go through; and this without assurance that the merger would prove successful.

Since we have not gone into detail, these points are suggested without further comment:

Don't wait—go out and look.

Seek the product—and then appraise the company behind it.

Size up your own company—what you have that would make a company pick yours to sell out to. This is a seller's market.

Much of the planning, exploring, screening and investigative work can be in common before the "make-or-buy" decision between internal development or outside acquisition.

ORGANIZATION AND CONTROL

There can be no "one best way" for every company to organize and control their new product function. However, we will expand on one way for new product organization that is gaining ground rapidly right now. Much management thinking has culminated in the concept of a "new product" or "product planning" department. An examination of the organization and operation of these departments is illuminating.

The typical history of these departments gives a flavor of their present and future characteristics:

Executive committees, representing the decision-making authority of a company, find themselves swamped as their new product programs have accelerated.

Normally, they turn first to the creation of a subcommittee for new products, charged with responsibility for evaluation or the coordination of new products, or both.

These committees find they need data from several units of the company in order to reach sound decisions, so that they are saddled with the unwieldy process of coordinating a great many third-echelon people.

A surprising number of companies, at an ever-increasing rate, are turning toward putting one man in charge of directing and coordinating the new product job for top management. Committees may or may not continue.

A new product department is not the best answer for every company. We have created and installed several, but we have recommended several other approaches based on a specific company's individual requirements.

We find new product departments (or product-planning departments, whatever the name) reporting in only three places, always directly and at a high level:

To the chief executive.
To the top R & D officer.
To the top marketing officer.

However, the incidence of reporting relationship is 60% to top management, as indicated by analysis of 47 departments.

Company size affects this plan:

We know few smaller companies that have, as yet, full-time new product directors. The executive committees continue to make these decisions, just as they get along without a lot of other specialists. However, we know new product managers in companies under $15 million of sales.

It is in the medium-to-large companies that these departments are appearing in considerable numbers.

In multi-division companies we find a pattern developing of "new product" departments at two levels. Each product division has a new product job to do within its technology and markets; but there is also a corporate job, not only of coordination, but of spawning new divisions.

The pattern selected, of course, depends on the nature of the business, its over-all organization and personnel.

The following are typical major responsibilites in new products development:

President

Determines company objectives.
Approves new product program.

Authorizes development, testing and commercialization of each new product.
Conducts final acquisition negotiations.

New Products Department

Recommends new product objectives and program.
Plans exploration activities.
Makes screening decisions.
Develops specifications.
Recommends development of new products.
Investigates acquisitions and recommends negotiation.
Coordinates testing and pre-commercialization.
Directs interdepartmental teams in all stages.

New product departments usually have some responsibilities that can be selected from the foregoing list. Some departments are only for evaluation in early stages; some principally for coordination in later stages; some have only incidental responsibility for acquisitions.

Patterns of internal organization shed further light on the nature of this function. The first specialist to appear usually will be a market research-type, the next a scientist-type of respected abilities from the lab, and finally an administrative-type to keep the operations straight and on paper. Most departments are little more than this size, generally about 4 to 5 men. There are a number of one-man departments. We know of one with over 200 employees.

As you can see, then, this is generally conceived as a small staff unit whose job is not to do the work but to help and coordinate those who are doing it. The technique of growing importance is to organize a product team around each product under development.

The basic neeeds are for continuity of effort and knowledge through all stages and for continuing cooperation between all departments.

The nucleus of the team for a specific product should be formed at the specifications stage so that departments to be affected by this product have a hand in cutting out their own tasks and defining the means of their accomplishment.

As the product evolves, the locus of major emphasis shifts from one department to another, but the continuity is maintained.

We have said earlier that top management is responsible, but let's be more specific about *what* this responsibility is. Largely, top management is responsible for a series of major decisions between stages, on whether or not to proceed with the next. Top management acts at these principal decision points.

1. Sets company objectives and approves fields of interest.
2. Approves development projects (for new products).
3. Approves the testing program for developed products.
4. Authorizes full-scale commercialization for tested products.
5. Makes necessary decisions to change commercialization programs.

BASIC PRINCIPLES

The following is a summary of basic principles involved in successful new product development.

1. *Business strategy is expressed in products; product programs are the foundation of forward company planning.* A company can be no more successful than its products will allow it to be; without definitive new product programs, advance planning is indefinite and incomplete.
2. *The new product program is a top management responsibility.* This is a responsibility that cannot be delegated without abandoning a primary responsibility for leadership of a business.
3. *The new product function should be organized as a top executive staff function, headed by a manager of stature adequate for coordination of vice presidents.* There are many ways to tailor this principle to fit each company's situation, by department or committee. An example of new product organization appears in the May issue of the *Harvard Business Review*, a case history of S. C. Johnson & Sons, Inc.—the Johnson Wax Company.
4. *Organization and control should be established in conformance with the stages of new product evolution.* This concept of planning and control, as adapted to industry characteristics, has been highly valued in programs we have developed and installed for our clients.
5. *Coordinated new product effort is best achieved through interdepartmental product teams, representing all function areas of the business, tailored to fit the characteristics of each product.* There seems to be no effective substitute for this approach. We know about a dozen ways to do it, each of which may work or not work in other cases.
6. *A definitive program, carefully planned and closely managed, significantly improves new product results.* Wherever a company has undertaken a *sound plan* to achieve better management leadership and control of this vital activity, they have been generally pleased with better results.
7. *New idea creation can be directed and controlled to achieve improved pertinence and quality of product ideas.* Quantity of ideas is more a problem than a solution. The requirement is for better quality and increased pertinency.
8. *New product selection is accomplished by a continuing series of evaluation in all stages: no single screening is adequate.* One magic screening will not do the job properly, despite popular literature to the contrary.
9. *Selection standards for products to be developed should be upgraded persistently to achieve an ever-increasing yield from available manpower and resources.* It is no trick at all to fill a lab with "pretty good" ideas. But, most companies have just so much in the way of resources, and the trick is to capitalize these at a minimum return, by recognizing and exploiting real bell-ringers.
10. *Product planning requires development of specifications and a program for each product prior to laboratory project.* Without preproject authorization management does not have control of the new product program; each product idea should be framed as a business proposition and so evaluated, as a basis of such authorization.
11. *Market requirements and opportunities are the primary consideration in product planning.* It is pretty conclusively demonstrated by experience that it is much harder to sell (at a profit) than it is to make a product in the first place; most products benefit if planned and programmed from the starting point of market needs and opportunities.
12. *Company acquisition should be integrated with internal development to achieve a balanced new product program.* These two programs are complementary and should be keyed to each other as mutually supporting activities.

CONCLUSION

We have undertaken to demonstrate these major theses:

That new products are indeed the key factor today in company growth, and even in survival.

That this is a function of business—however complex—that can be identified and described.

That there are effective methods to manage—to organize and control—this vital function.

The recommendations we have made are general ones, which clearly must be adapted creatively to meet specific company characteristics. The skill of this adaptation can mean the difference between major benefits or more troubles. Some disappointed companies are correct on principles, but have not yet found the right way to make them work.

However, most new product problems do have at their root the violation of one or more of the concepts and principles outlined here. Successful programs can be built, with confidence, around these.

Job Simplification Versus Job Enlargement

Psychological Aspects

by **NEIL D. WARREN**

Professor and Head, Department of Psychology, University of Southern California

WALKER and Guest begin their monograph "Man on the Assembly Line" with a quotation from Henry Ford II which will serve to introduce this discussion (12):

> Machines alone do not give us mass production. Mass production is achieved by both machines and men. And while we have gone a long way toward perfecting our mechanical operations, we have not successfully written into our equations whatever complex factors represent Man, the human element.

Paradoxically, the need to know more about the human element may be greater than ever as industry moves into the era of electronic controls.

THE PROBLEM OF REPETITIVE WORK

From the time of Adam Smith, social scientists have expressed concern about the effects of simplified and repetitive work on the worker. Smith warned that a lifetime of such work would cause the worker to become "as stupid and ignorant as it is possible for a human creature to become" (4). This prediction has certainly not been fulfilled, although without the counteracting effects of universal education, more leisure, etc., it might have been. Early in the 19th century Sismondi believed that division of labor would not only cause man to lose intelligence but, also, "vigor of body, health, and cheerfulness" (4).

The criticism is still being made under the more modern concept of morale in industry. Within the last three months no less a person than the President of the United States took occasion in a press conference to contrast the task of the artisan with the simplified, repetitive task of an assembly line worker.

Relatively little scientific research has been done in this area and the results are not as clear as we need them to be. Critics have argued that extreme specialization degrades the worker, diminishes his satisfaction with the job, and tends to decrease his efficiency. Much more evidence is needed about all these effects before we can be sure that they really exist and to what extent. In the meantime, I would like to present some of the evidence and attempt to evaluate it.

THE TREND IN INDUSTRY

First, let us attempt to see the outlines of the problem as it exists in industry.

In 1950, Walker reported that the effort to reduce repetitive work through job enlargement affected about one-half million workers (11). This is a relatively small portion of the total work force. Moreover, the movement does not seem to be sweeping the country. In 1955, Davis, Canter, and Hoffman reported the results of a survey involving interviews in seven manufacturing companies and questionnaires from 24 others ranging in size from 97 to 14,000 workers (2). They reached this conclusion:

> Individual tasks are combined into specific jobs so that:
> 1. Specialization of work is achieved whenever posible by limiting the number of tasks in a job and limiting the variations in tasks or jobs.
> 2. The content of the job is as repetitive as possible.
> 3. Training time is minimized.

Although these investigators reported that job satisfaction was a stated requirement for job design they could find no evidence of use of a criterion for determining that the work actually was satisfying to the operator.

Interest in job enlargement has been increasing during recent years and it is encouraging to note that efforts are being made to evaluate its effects. The problem still remains, however, with possible new aspects as the result of increased automation.

THE NATURE OF BOREDOM

The villain blamed for harmful effects of repetitive work, is in general, monotony and its consequence, boredom. It is easy to determine if a task is repetitive, sometimes difficult to determine if it is perceived as monotonous and boring. Much of the work of the artisan is just as repetitive as that of the worker on the assembly line or in the specialized office situation. Moreover, many activities people choose for recreation or hobbies are repeti-

tious but, obviously, not boring.

Monotony is defined by Webster as sameness or lack of variety. Boredom is a state of mind involving weariness, fatigue, disinterest, and dislike. Sometimes monotony produces boredom, but not always. Productivity, work efficiency, job satisfaction, mental and physical well-being suffer as a consequence of boredom—not merely as a result of repetition or monotony.

Another source of monotony than that produced by repetitive work is the monotony of inaction. Monitoring an automatic machine, for example, is likely to be more boring than operating one less automatic.

I have been told that, in one modern highly automatic submarine, a submariner is required to monitor a panel of instruments. This is an important task requiring that he remain alert to deviations from desired readings. In the case of one instrument he is required to make frequent adjustments for variations in readings. The adjustments could easily be made completely automatic and this seems a very low level use of human capabilities. Nevertheless, it has been found necessary to keep the monotony from reducing his attention to the danger point.

In most cases when a worker has very little to do, as in watchkeeping, his efficiency suffers. He fails to respond at all or he responds after long delays. His performance usually becomes more erratic (14). There is evidently an optimum amount of activity for vigilance and responsiveness. Either too much or too little appear to reduce efficiency.

Automation promises to aid in the effort to deal with monotony by substituting the electronic computer for the human. Many of the routine, repetitive tasks can be taken over by the machine. This would permit the worker to concern himself with those aspects of industry in which man is still superior to the machine: basically those requiring exercise of judgment. This is a management function and the field is obviously limited. On the other hand, monitoring of automatic operations threatens to be just as monotonous as repetitive work.

INDIVIDUAL DIFFERENCES IN MONOTONY TOLERANCE

One approach to the problem of monotony has been to attempt to select persons less susceptible to boredom. Since boredom is an attitude which varies widely among people in the same situation it should be possible to distinguish among them.

Munsterberg, in 1913, made early attempts to choose workers whose interest in repetitive work would not diminish with time (9). Wyatt, Fraser, and Stock in 1929 said that temperamental characteristics determine suitability for repetitive work (13). Also, they suggested that persons of "mediocre intelligence" would be most able to adapt to such occupations. Numerous studies have been reported which appear to support this belief. Unfortunately, in most instances the studies leave much to be desired in scientific rigor. A few recent studies have cast doubt on the idea. Heron, for example, after controlling effects of age and experience, reported that susceptibility to boredom was unrelated to mental ability. Similar results have been found by Smith who concluded that the relationship between intelligence and boredom is by no means established (10).

The characteristics which Smith believed distinguished the worker not susceptible to boredom are harder to measure than intelligence. The person who is satisfied doing repetitive work, she suggests, is one who is contented with the existing state of affairs, placid, and perhaps rigid. Her study supported the belief that

> . . . the susceptible worker is likely to be young, restless in his daily habits and leisure-time activities, and less satisfied with personal, home, and plant situations in aspects not directly concerned with uniformity or repetitiveness.

Whatever the specific human characteristics involved in monotony susceptibility, the evidence seems conclusive that there are individual differences which will complicate the attempt to establish an optimum degree of job simplification or enlargement for any given industrial situation.

Incidentally, it has been found by several investigators that occupations which do not involve highly simplified, repetitive work can be boring. Professional workers, school teachers, and others have reported boredom with their work.

A job is boring only if the worker perceives it as boring. This is true for any occupation regardless of level.

DE-PERSONALIZATION

Walker and Guest have emphasized another psychological aspect of the highly simplified job, that of "depersonalization" (12, p. 161). This is the worker's experience of anonymity within the mass of fellow workers. What he does is simplified and standardized to the point that he is permitted no expression of individuality, either in product or in method. Just as standardization permits interchangeability of parts, so the worker finds himself interchangeable and replaceable. Walker and Guest reach the following conclusion:

> We suggest that the sense of becoming *de-personalized,* of becoming anonymous as against remaining one's self, is for those who feel it a psychologically more disturbing result of the work environment than either the boredom or the tension that arise from repetitive and mechanically paced work. . . .

No doubt there are individual differences among workers in susceptibility to "de-personalization" just as there are for monotony tolerance. I know of no quantitative studies of the problem, however, nor of any study of the variables affecting the worker's susceptibility.

Other writers have described this aspect of assembly line work in more literary terms. One report, for example, says "The magic power of the conveyor attracts workers. The worker's personality disappears. Yet the worker

gets used to it."

Still others have emphasized the importance of "value" or "significane" to the worker. Hans Rupp, for example, saw in the assembly line situation opportunity for providing the worker an awareness of the over-all meaning of the production process (4). Others have recommended placing samples of the finished product where they can be seen by the workers to provide the element of significance.

On the other hand, evidence that satisfaction with the job is causally related to productivity is inadequate. As a matter of fact, several studies have indicated that no such relation exists.

THE PROBELM OF CRITERION

It has often been pointed out that the quantity of output is not the sole basis for evaluating a given job design. Employee turnover, absenteeism, waste, and accidents are among the factors that must be considered. These appear to be better criteria of job satisfaction than productivity in any highly mechanized situation.

Levy-Seboyer, for example, reported that, while fatigue resulting from monotony did not necessarily cause a reduction in output, there was often a greater irregularity in precision work (5).

Blum says that the idea that production is a very important criterion of industrial efficiency needs re-examination (1). He calls for much more basic research before production figures can be taken out of the realm of theory. He describes the Employee Relations Index developed at the General Electric Company in Merrihue and Katzell (8). The ERI includes such items as absences, separations, disciplinary layoffs, visits to the dispensary, work stoppages, accidents, grievances, etc. These are expensive items and must be considered in any evaluation of the efficiency of an industrial process.

In his persuasive article on job enlargement, Elliott put it this way (3):

> Monotonous and uninteresting work tends to increase costs as high fatigue and lack of job interest mean less productivity and higher costs. The bored, uninterested employee has more absences, more grievances and more frustrations, all of which adversely affect the quantity and quality of his work. When we add the cost of these extra absences, extra grievances and extra poor quantity and quality of work to the cost of relief periods, music, color dynamics and the like, we become increasingly aware of the fact that the monotonous, uninteresting job can be costly. Yet how often do we take these indirect costs into account when we make a change to reduce costs which increase job monotony?

JOB ENLARGEMENT—A SOLUTION?

The question posed for this discussion, Job Simplification *vs.* Job Enlargement, must be answered in terms of both criteria—productivity and cost. It is apparent that, in the short-range view at least, productivity can be increased by specialization. It is evident that some students of this problem believe the cost is undesirably high. It is certain, however, that in the long run consideration of employee needs will help decrease total economic cost of production and increase efficiency.

Job enlargement may be one way of achieving this objective. Controlled research on the problem is needed. The studies of monotony and de-personalization, although frequently deficient in scientific rigor, give some evidence of the negative aspects of extreme job simplification. The positive results of job enlargement are still given largely in anecdotal form. This is a research problem and methods for finding the answers are available.

An example of research in this area is found in a study by Marks (6). He made comparisons of quantity and quality of output, and of job satisfactions for different types of job design.

The first was a Line Job Design which had been in effect for over two years. The workers rotated among nine stations doing highly repetitive tasks at a pace determined by a conveyor belt.

A Group Job Design eliminated the conveyor by grouping the workers around tables using the batch method. Otherwise, the factors of responsibility for quality and productivity were little different from the Line Job situation.

In the Individual Job Design the workers were situated at individual tables. All facilities for complete assembly of units were available in easy reach. Each worker had full control over productivity and quality; setting her own pace and inspecting her own assembled units.

Marks reported that the Individual Job Design resulted in an immediate decrease of 75 percent in defects due to poor workmanship over the Line Design. There was a smaller decrease in the case of the Group Job Design.

After six days in the Individual Job Design situation, average productivity had reached the level of the conveyor line rate, a rate established after two years of experience on the line. The study stopped at this point without finding whether further improvement was possible. At the same time the study showed improved attitudes of the workers toward their work and a decreased amount of frustration.

Marks summarized his findings in the following way:

> Sufficient information was obtained from this investigation to develop a short list of principles based on the Job-Centered Theory of job design. For example, as long as reasonable safeguards and certain technological conditions exist and if the worker is sufficiently skilled and "willing," it is desirable to give him individual control over those aspects of the work for which he has been assigned responsibility, e.g., productivity, quality, evaluation of proficiency. Essentially this principle contradicts the general philosophy presently used in job design, i.e., minimizing responsibility and maximizing specialization. However, the findings reported here clearly confirm what many have suspected, that there is a point of diminishing returns to specialization.

The key aspect of the experimental changes in job de-

sign introduced by Marks is the introduction of individual responsibility. He reports no changes in the mechanical operations of the tasks. Indeed, he suggests some possible further improvements could be made by simplification of the work methods and improvement of the work layout.

There is no conflict between *simplification* and *enlargement*. Elliott has emphasized that what is needed is *work* simplification and *job* enlargement (3). It is a mistake to simplify jobs, he believes, since this is what causes boredom and lack of interest. Job enlargement, on the other hand can result in work simplification through consolidation of activities.

Marks puts it in a slightly different way (7):

> . . . Within my framework, either an increase or decrease in specialization could bring about the benefits that are sought—depending on the control that the individual is able to exercise in order to fulfill his responsibilities. . . .

It is easy to over-simplify the concept of motivation of the worker. Whether pay, security, advancement, working conditions, benefits, prestige, or some other factor are important motives, and in what order they affect the worker are matters of wide individual differences. Often the worker is most strongly motivated by the factor he lacks—particularly if he perceives it to be attainable. Most studies find that pay is not the most important incentive, and that age, sex, marital status, intelligence, and background of the worker play impotrant roles in determining the importance he attaches to each motivation.

Social scientists have maintained that there are motives associated with work itself, that there are many needs expressed and fulfilled in work. Mastery of the job and pride of achievement, says Blum, are two such values (1). Individual responsibility and completion of a started task are others. Work should be meaningful; it should have some social significance.

One study of office workers was summarized in the following way (1):

> People are more effectively motivated when they are given some degree of freedom in the way in which they do their work than when every action is prescribed in advance. They do better when some degree of decision-making about their jobs is possible than when all decisions are made for them. They respond more adequately when they are treated as personalities than as cogs in a machine. In short, if the ego motivations of self-determination, of self-expression, of a sense of personal worth can be tapped, the individual can be more effectively energized. The use of external sanctions, of pressuring for production may work to some degree, but not to the extent that the more internalized motives do. When the indiivdual comes to identify himself with his job and with the work of his group, human resources are much more fully utilized in the production process.

CONCLUSIONS

Many authors think of automation as the best escape from mechanized work, and perhaps it is. If the routine, repetitive functions of office and factory can be performed by machines, as in fact many of them now are, man can be freed to perform the functions in which he excels the machine. He will need more skill and knowledge than at present. The days of the unskilled worker are numbered, if we assume the recent trends will continue. Between 1910 and 1950, the male labor force increased from 13 million to 20 million—not including farm labor. For the same period unskilled labor decreased from 5.37 million to 3.67 million.

As routine work is reduced it becomes necessary to provide meaningful activity for the worker. This should not be difficult. In general, he will need more knowledge, a better understanding of the entire operation. His job will be automatically enlarged.

This is in the future. We still have the problem of the assembly line and the specialization office job. What principles can be applied to the design of these jobs?

This question cannot be answered simply. The variables are far too complex. They include such aspects as individual differences among workers, difficulties in development of criteria, and control over contaminating factors. This is a problem for research—research sufficiently elaborate and extensive to secure useful answers. Research of this sort cannot be satisfactorily accomplished in the laboratory, or by the individual scientist working in the area of his particular orientation. The research-team approach, so successful in other areas, should be adopted.

Davis, Canter, and Hoffman have urged this approach in the following quotation (2).

> The nature of job design research and experimentation should reflect the multi-dimensional character of the problem. The problem area is amenable to attack from many quarters, under certain requirements. Paramount among the requirements is that job content must be a central theme of all experimentation, with other variables included in various experimental designs. In addition, multi-dimensionality and interaction among variables calls for a problem-centered research-team approach. . . .
>
> The types of data that will be required will call for research and field studies that may need to be conducted by industrial engineers, industrial psychologists, sociologists, anthropologists, economists, and researchers in personnel administration and industrial relations. Obtaining the data needed will require that studies be conducted that will range from determining and measuring "meaningfulness" as applied to operations, work methods, work groups and jobs, through the determination of long term total economic cost criteria, to the determination of the means of designing processes, systems, methods and product components in terms of job needs.

It is premature to generalize in the absence of such research, and futile to urge a reversal of the trend toward specialization without more evidence. The studies that have been reported, however, permit the prediction that one principle of job design will be that the needs of the workers with regard to work itself are as important as his needs for financial reward, security, or status.

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Job Design

by **R. N. LEHRER**

Professor and Chairman, Department of Industrial Engineering, The Technological Institute, Northwestern University

THE Industrial Engineer has been accused of simplifying work to such an extent that man cannot function as a human being. Simplification, fractionation of jobs, specialization, standardization, and de-skilling of work, have all been regarded as means of achieving more economical production by both the Industrial Engineer and by management.

Frequently, however, the over-simplified job is *not* economical; it results in man being placed in conflict with himself.

Job enlargement has been proposed as a remedy for over-simplified jobs. Although job enlargement has proven to be very effective in many situations, the simple enlargement of jobs is not sufficient by itself. Jobs must be *designed* so that they are both mechanically efficient, and efficient from the standpoint of the dignity of the individuals performing the work. There is ample experimental evidence to indicate rather conclusively that jobs can be *designed* to achieve both of these objectives. This requires a clear recognition of the mutual objectives of the individuals and the organization, a sincere belief in the dignity of man and his work, participation (on the part of everybody involved) in solving work problems, and an awareness of the mechanical aspects of efficient work methods.

CRITERIA FOR JOB DESIGN

In order to appreciate the job design approach to achieving both economical production and satisfaction from work experience, it is necessary to clarify the basic objectives of business organizations. These, for profit making organizations, can be stated as: 1. "to make money"; and 2. "to make money." (These same objectives can be re-phrased for the non-profit or service organization.) Although these appear to be identical objectives, they differ considerably. The first "to make money" is a short range objective. It implies immediate survival and the short range prosperity of the organization. The second "to make money" deals with the long run objectives of the organization. It is concerned with survival over a prolonged period, and the proper relationship of the organization with society and the economy as a whole. Both of these objectives are very important.

In addition to the two basic objectives just stated, an over-riding obligation of all organizations is service to society. This is quite fundamental. If an organization does not fulfill its basic service obligation, the other two objectives cannot long be achieved, for society will exert "pressures" upon the organization in order to "force" corrective action. This feed-back or corrective action may be rather slow, and it may be altered by changing social values. But it is present, and it constitutes an important factor in what is "right" in job design. If, for example, we are making "blithering idiots" of our working force (by removing all challenge and responsibility from work, as some humanitarians claim), this will have a drastic effect in the long run upon our production processes, and what is considered to be socially acceptable relative to work requirements.

The typical assembly line organization of production is an example of preoccupation with achieving short-run objectives while ignoring long-run objectives. Most of these arrangements have resulted from an attempt to minimize short term or direct costs. Very little attention has been given to the broader nature of the problem nor to the "human" values involved in the work situation. Many of these installations do not even achieve minimum direct costs, for the only challenge remaining in the work is one which leads the workers to a desire to "'beat the system" by preventing it from working as effectively as it could. It is unfortunate that this enthusiasm has not been guided toward more noble objectives.

JOB SATISFACTION

Consideration of the humane aspects of work has led

many individuals to conclude that job satisfaction is a factor that can be used to measure the long range and social criteria of job design. Unfortunately, the "happy" worker is not always a good producer, and it is extremely difficult to establish the relationship between "happy worker," "good producers" and actual long-range company and social objectives.

The subject of "satisfaction vs. productivity" has been examined by a number of investigators (for example, see Milton Gordon's paper "Leadership for Production"). Many studies indicate that the "happy" worker is the "productive" worker. A significant number of studies indicates that the "happy" worker is neither more nor less productive than the "less happy" or "unhappy" worker. A few studies indicate that the "happy" worker is not a good producer. Interpretation of the results of these investigations must be made very cautiously. Criteria for measuring "satisfaction" are elusive, and perhaps lacking validity and reliability in measurement. The criteria for evaluating "productive" workers are equally elusive and lacking in validity and reliability.

Even though much research has been done in investigating the matter of job satisfaction as it relates to job performance, no clear-cut relationships have been determined. This is particularly important when attempting to relate these factors to the basic objectives of business operation. The most that can be stated is:

A "challenged" and "motivated" worker is likely to be a productive worker. His means of being "productive" may be related to short term job performance, or to helping his organization achieve success relative to long-term performance.

JOB ENLARGEMENT

As I previously stated, job enlargement has been proposed as a cure for all the ills associated with oversimplified jobs in modern business and industry.

The simple enlargement of jobs is not sufficient by itself to achieve what is desired. Jobs must be "enlarged" or *designed* with very broad criteria in mind, and not enlarged just for enlargement's sake.

Job enlargement can be viewed as a broadening of the human and humane content of an individual's work life. This can be accomplished in several ways:

1. We can "broaden" jobs by physically expanding them. This can be done by combining various related or sequential activities into a larger homogeneous job assignment, by providing "rotation" of work assignments, following the "craftsman" approach, etc. This approach is primarily an alteration of the "mechanical" aspects of work, which often results in a change in the "human" and "humane" aspects as well. Boredom may be reduced, a better understanding of how one small job relates to others and to the product may be fostered, better social contacts may be established, etc.
2. We can "broaden" jobs by adding an extra dimension which is only indirectly related to the mechanical aspects of the work. This is frequently accomplished by allowing direct participation of the workers and supervision in the solving of work problems that are related to their jobs and their on-the-job lives. This approach may not appreciably alter the "mechanical" aspects of the job, and may frequently result in a simplification or narrowing of the direct job requirements. However, when the extra dimension is considered (the use of the really unique human and humane characteristics of man) a considerable broadening of man's contribution to the organization has been achieved.
3. We can also "broaden" jobs by concentrating on "human relations" and "welfare" activities within the organization. Although both of these terms may have unfortunate connotations, much good can be achieved by sincere policies and daily actions that prove to our fellow man that there is validity in the concept of human dignity—both on-the-job and elsewhere. Great benefits can be achieved by better understanding of mutual problems and objectives, a fostering of pride and esprit-de-corps, by enjoyment of association with fellow workers and an organization of high purpose, and by positive dynamic leadership from all supervisory personnel.
4. We can "broaden" jobs by integrating all of the above three approaches into the daily work habits of all employees within an organization. This will assure an effective organization: one that recognizes the advantages of cooperative action and individual initiative, and one that is in friendly competition with itself. This can be done by means of job design.

We shall now consider some specific examples of job changes relative to the various means of achieving job enlargement, and how these can lead to job design based upon broad criteria of economic and social desirability.

LINE VS. INDIVIDUAL JOBS

The assembly of a small mechanical unit containing from twelve to twenty components was achieved by an assembly-line arrangement. Twenty to thirty workers were stationed around an oval conveyor belt which carried fixtures to hold the assembly as it was built up. Each one of the workers performed a very small part of the total assembly work.

The assembly line arrangement was quite successful, and achieved good production results. Production was rather uniform, the quality level was high, and there were very few supervisory problems. Production averaged between eleven and twelve thousand units per hour.

The company, however, was not satisfied that the "line" arrangement was as effective as it could be. They recognized that not all assignments were to capacity, and that there would always be some "imbalance" even if all assignments were "balanced," for superior individual performance was held back by average performance. They also recognized that each individual worker was required by the subdivision of the total assembly work to make several nonproductive motions for each productive one. They decided to re-evaluate the production scheme.

The first analysis revealed that several minor "mechanical" improvements could be made, but that it was very difficult to do much in the way of improving interpersonal contact among the workers and with supervision. The line arrangement tied the individual to his work station, and allowed social contacts only with the individuals on each side. Even so, some improvements were

thought to be possible. The supervisory personnel were encouraged to cultivate the "social" aspects of work, and a very desirable situation was developed. The entire group developed a cooperative team attitude, they seemed to enjoy improving their performance, and they were encouraged to rotate jobs, sing, and be in friendly competition with one another. The results were very good. A 10 percent production increase was achieved.

The desirability of individual work stations was next considered. This arrangement would allow individual control over quality and quantity of production, and the performance of the entire assembly job. The more complex job, however, would extend the learning period from one week to about eight.

The potential rate of production for the individual work stations was almost 20 percent above the per man potential of the assembly line.

Several individual work stations were constructed as production requirements exceeded the increased capacity of the assembly line. These were arranged such that workers were paired on opposite sides of tables, facing each other. Supervision worked very closely with the workers, training them in the correct method of performance but allowing opportunity for expression of individuality and participation in refining the job method. Learning required approximately eight weeks, as anticipated. The anticipated production increase was exceeded by an additional 10 percent.

Further increases in production were achieved through manipulation of the social patterns of the work arrangement. As more individual work stations were needed, the workers were arranged such that the dominant individuals (or informal leaders) were placed in the spots offering the greatest opportunity for contact with the other individuals. These persons were then encouraged to develop further methods improvements, some of which were very subtle. The contrived social grouping resulted in a natural penetration of these improvements to all workers. An additional 20 percent increase in production was obtained.

THE HAWTHORNE STUDIES

One of the classic studies of human behavior in a working environment is the research conducted at the Hawthorne Works of Western Electric Company during the twelve years from 1927 to 1939. These studies were originally undertaken to evaluate the effect of intensity of illumination on the efficiency of output of workers. The original objectives of the study proved to be very inadequate, and the results of the study were negligible. However, the failure to obtain results concerning the original objectives was the very reason the project continued for many years and finally yielded very significant results relative to the human factor in industry.

The Hawthorne Works of the Western Electric Company was regarded as a very progressive company from a technical and a human relations standpoint. It had always shown concern for the well-being of its employees and had maintained a high standard in the matter of wages, working conditions, vocational guidance, and employee benefits. The company enjoyed good industrial relations and had every reason to believe that the worker morale was high and that the employees had confidence in the abilities and motives of the company management.

ILLUMINATION STUDIES

The initial investigation failed to show any simple relationship between illumination and employee behavior. Even though the research was not aimed at increasing the production of the employees, rate of production was used as one of the criteria for evaluation of the experimental results. The rate of production seemed to be greatly influenced by the employees' interpretation of what the observers and management expected of them. Simple changes or re-arrangement of the illumination, even though the intensity remained the same, caused changes in output. The researchers concluded that these results were obtained due to the influence of additional factors of a psychological nature that they were unable to control. This led directly to the second phase of the extended investigations.

TEST ROOM STUDIES

In an attempt to control the effect of psychological factors, the experimenters decided to continue their observations with a small group of workers who were isolated in a separate test room. They anticipated that the psychological factors would in time disappear if the group were asked to cooperate and if they were free from the distractions of their normal working environment.

The experimentation in the test room was broadened to include consideration of other physical influences in addition to illumination, such as rest pauses, free snacks during rest pauses, changes in the length of rest pauses, change in the wage payment scheme, shorter hours, and a change in the number of days worked per week. The test room included bench and assembly equipment identical with that used in the regular department, and instrumentation for measuring output rate, weather conditions, temperature, humidity, and so forth. Six average girl operators were selected for observation. Five of them were to do the work, while the sixth supplied parts and materials as needed. An observer was assigned to the test room to maintain records, arrange the work, and develop a cooperative spirit on the part of the girls. Eventually, as his task became more complex, several assistants were assigned to help him.

PARTICIPATION

Prior to the experimentation, the girls were called to the superintendent's office for an explanation of the project. They were informed that the objectives were to eval-

uate the influence of changes in working conditions, and they were cautioned to work normally and not to make a race out of the test. There were many subsequent conferences as experimental changes were made. The girls were always asked for their comments, and certain changes that did not meet with their approval were abandoned.

RESULTS OF TEST ROOM STUDIES

The results obtained from the test room experiments indicated that rate of production in each experimental period was higher than in the preceding period, even though some periods duplicated the physical conditions of earlier periods. The obvious conclusions were that changes in physical factors were more than offset by other, more potent forces. These other, more potent forces were related to the psychological and social environment that had developed in the test room. Contrary to the expectation of the researchers, the psychological factors (that is, those things that were suspected of having caused confused results in the original illumination experiment) did not in time disappear.

Each girl was producing more in the test room than she ever had in the regular department. This was done without any conscious effort. The girls liked to work in the test room. They enjoyed their association. They were important. There was an absence of the regular supervisory "control." They could work without anxiety. They could talk to one another. They were a vital part of an important venture. The results they produced could lead to important improvements in the working conditions.

An extensive interviewing program was initiated at the completion of the test room experiments. These interviews were aimed directly at investigating human relations and were non-directive in nature. The employees were encouraged to talk about anything that was bothering them and to express themselves freely. The interviews eventually extended to more than 21,000 in number. The results strongly indicated that the employees were banding together informally in order to protect themselves against practices that they *thought* were a menace to their own welfare. Remember, these were results from an organization that was highly interested in the welfare of their employees—an organization with good employee morale.

The interview results also indicated that employee behavior was a highly complex matter, influenced by the individual's previous experiences and mental health and by the social factors sensed by the individual both on and off the job. There was strong indication that human behavior in this situation was not guided by logic alone. The wage incentive plan, designed logically to encourage the working force to increase productivity, was interpreted as a challenge to "beat the system" by straight-line output (the group adopted standards that they felt were proper, and no one exceeded them by very much) and by informal practices to enforce the group-established standards.

WORK SITUATION STUDIES

The interview program was followed by intensive observation and interview of selected groups working in their normal environment. These investigations revealed further evidence of informal social codes adopted by the work group. Some jobs were made to appear very difficult and involved, when in reality they were very simple. Production was established at levels regarded by the group as being correct to protect their interests. Technical changes were opposed, even when in the interests of making the jobs easier and better and the product more economical and salable. There was a conflict of interests, which caused dissatisfaction and unrest.

Finally, the series of experiments concluded with another test room investigation. The influences of the psychological factors found to be so potent in the previous test room investigation were recognized and guarded against. As a consequence of these precautions, the results were much different. Many things were found to be going on in the test room that should not have been happening —particularly not in an organization that was progressive and alert to the employee's needs. Production was held to the "socially acceptable" level established informally by the employees. Pressure was brought to bear on the fast workers. Technical changes were unofficially but effectively resisted.

COMMENTS

The entire subject of the extensive Hawthorne Studies makes fascinating reading for the student of human nature. Two generalizations can be stated concerning the entire investigation:

1. No change in the physical or financial conditions of work had a foreseeable and calculable effect in terms of output unless it was connected with the psychological and social attitude of the worker. The psychological and social attitude of the worker includes the personal bond between the worker and his work, the meaning of work to the individual, the individual's integration with the group, the individual's recognition of his own goals and objectives and of those of the group and the company, and the relationship of the supervision with the individual and his group.

2. The logic of efficiency ran counter to the logic of sentiment, except in those cases where the logic of sentiment was oriented in the direction of psychological and social values that produced efficiency as a by-product. There was considerable evidence to indicate that workers will react unfavorably to any behavior forced upon them from above without their participation in shaping the decisions and understanding of objectives and means for achieving the objectives.

RESISTANCE TO CHANGE

The Harwood Manufacturing Corporation, maker of pajamas, employs about 500 workers. It is regarded as a progessive company, alert to employee problems and public relations. Its policies are regarded as fair, liberal, and progressive. A high value has been placed on fair and open dealings with employees, and they are encouraged to take up any problems or grievances with the manage-

ment at any time. The supervisors are given help and encouragement in finding solutions to their own problems.

By most all standards, this company could be regarded as a good example of a smooth-functioning organization. However, one of the basic characteristics of the business was causing some difficulty. Competitive forces and styling changes made it imperative that jobs be changed rather frequently. The necessity of these changes was rather obvious to the entire organization, but there was evidence that employees resented and resisted changes—even though the changes were essential to the continued success of their company.

Resistance to change in job methods and assignments was demonstrated by sub-standard production on transferred jobs, extended re-learning periods, hostility to supervision, and excessive quits. The company management was interested in investigating this problem, and so a research project was set up.

CONTROL

Three groups of employees were selected so that the groups were approximately equal in production performance, amount of re-learning that would be involved in a change, and the "we" feeling within the groups. The first group, used as an experimental control, was transferred to new work by the procedures normally used in the plant. A group meeting was held, the necessity for the change was explained, and the new job method and production standard explained.

REPRESENTATION

The second group was involved in developing change in work methods through representation. The entire group was called together and the importance of devising efficient production methods was dramatically presented to them. Management then proposed that the group select several of their members to help devise methods improvements, to be the subjects for time study in order to establish performance standards on the new job, to explain the new job to the other group members, and to help train the other operators. The group selected their representatives and the plan was executed as proposed. The "representatives" and the engineer developed improvements and a new production standard was established. The "representatives" of the group referred to the results as "our job" and "our rate," for they had actually participated in developing the new job. The new method and the production standard were explained to the entire group, and the "representatives" trained the other group members.

PARTICIPATION

The third group participated directly in the entire job change. A smaller group-size allowed an informal atmosphere that immediately led to direct participation of all group members. The importance of improving work methods was outlined in much the same manner as it was for the second group. The operators responded with numerous suggestions. Through participation of the entire group, the method was improved and a new production standard was established.

RESULTS

The control group behaved about as expected, based upon past experience with job changes. They evidenced resistance to the change, aggression against management, uncooperative actions with the engineer, hostility to their supervisor, deliberate restriction of output, and 17 percent quits in the first forty days after the change.

The group that participated in the job change through representation performed much differently. They recovered their production level rapidly, were cooperative, worked well with the engineer, had only one incident of aggression against their supervisor, and had no quits in the first forty days after the change.

The direct participation group performed even better than the second group. They recovered their previous production level rapidly, were cooperative, worked well with their supervisor and the engineer, had no acts of hostility, and had no quits in the forty days following the change.

COMMENTS

Again, we have seen evidence of the logic of efficiency running in opposition to the logic of sentiment, and evidence of the power of social and psychological forces in determining individual behavior. Restriction of output, resistance to and resentment of change, and aggression were caused by the threat to individual and group interpretations of their own welfare. Their inner security was threatened by change. Frustration led to overt behavior that seemed detrimental to individual, group, and company objectives.

Participation in job change produced dramatic results. Most problems associated with restriction of output, resistance to and resentment of change, and hostility were entirely eliminated. The group had been made a more active part of the entire organization. The problems of competition had been shared with the group. They have had their objectives clarified and have changed in the direction of improved productivity. Their jobs have been made more meaningful, more important, and more satisfying.

PRINCIPLES OF EFFECTIVE WORK[1]

The only formal principles or rules commonly associated with methods improvement are Barnes' principles of motion economy. These principles have been developed

[1] Based upon material from *Work Simplification—Creative Thinking About Work Problems*, by R. N. Lehrer, published by Prentice Hall, Inc., N.Y., 1957.

as an extension of the principles of motion study originated by the Gilbreths. They are subdivided into those related to the use of the human body, those related to work place layout, and those related to the design of tools, jigs, and fixtures. Even though these principles are excellent, they tend to encourage very narrow thinking about work problems, inadequate consideration of the human values of work, and concentration on the hand and body motions of individual operations to the exclusion of the entire broad criteria of job design. This is extremely unfortunate. Adequate consideration must be given to the entire work system and the human values of work if improvement efforts are to be truly effective. There are principles available that will guide efforts in this direction. These broader principles facilitate optimization of entire work systems rather than sub-optimization of individual operations.

Principle 1, *the law of conservation,* is basic to all of our work simplification efforts. Principles 2 through 4, *goal recognition, dignity of work activity,* and *self-determination,* pertain to the non-physical working environment and the development of a positive direction for the human factors that are so intimately associated with all work problems. Principles 5 through 8, *work elimination, smooth and balanced flow, effectiveness,* and *simplicity and directness,* deal with the improvement of work methods. Principles 9 through 12, *standardization and preplanning, quantitative evaluation, proper installation,* and *the dynamics of change,* relate to the unification, evaluation, application, and continued use of effective work methods.

THE LAW OF CONSERVATION

The law of conservation of energy and matter[2] states that, in a closed system, matter and energy can be neither created nor destroyed—only changed in form. This law may further be amplified to include an interpretation of energy as the potential for performing work. It represents the fundamental concept upon which all of our "improvement" efforts are based. This is particularly so when we consider the addition of *useful* as a descriptive modifier for the words *work, effort,* and *matter.* The objectives of job design are aimed directly at increasing the amount of *useful* matter and energy in the *systems* with which we deal. We want to increase the amount of *useful* work accomplished by the energy in our work-systems.

Consideration of the accomplishment of useful work implies that we desire to increase the efficiency of transforming the energy and material that is related to work performance. We want to increase the amount of useful work accomplished for a given input of energy and material, or we want to accomplish the same amount of useful work with less input of energy and material.

There is a difference between the two "resources" that enter our work system. The natural resources, or their derivatives, usually can be stored. If they are not used, they can be saved. Not so with our "human" resources. If we do not effectively make use of the human resources available at a given time, these are lost forever.

It is important to keep in mind the non-physical components of our work systems. In addition to transforming material and energy into a more useful form, the transformation itself should create useful non-physical results such as satisfaction and a sense of accomplishment and pride. This concept should permeate the entire organization and should be reflected in each and every job. It should be a daily concern of management, supervisors, engineers, and the man-on-the-job. Purposeful human activity that accomplishes production and satisfaction in the best possible way represents a sound and progressive organization..

The law of conservation can also be thought of as the law of waste elimination. Our improvement objectives are aimed at doing the most effective job of converting the energies and materials in our work system—which amounts to the minimization of waste. Waste of any kind should be minimized.

GOAL RECOGNITION

Each and every individual in an organization should understand the objectives of his organization; he should also understand his own personal objectives. Further, everyone should clearly know how these objectives are similar and can be achieved in a compatible manner.

Now this may sound a bit trite. But don't underestimate the importance of goal determination. Communication of ideas is one of the most complex problems facing American business. In addition, many organizations do not have clearly defined objectives, and they lack direction. Imagine the troubles a ball team would have without clearly defined objectives.

The objectives of an organization should be clearly and completely stated, and demonstrated by application in the daily activity of business life. Management should demonstrate that the entire organization has a common goal and that individual goal accomplishment is directly related to the organization's goal accomplishment. The importance of each individual and his responsibility should be clearly spelled out. The relationship of each individual task to the over-all goals of the organization should be made crystal clear, by word and deed.

DIGNITY OF WORK ACTIVITY

Human beings possess many characteristics that set them apart from other members of the animal kingdom. Prime in importance is dignity. Each man is an individual apart from all other mankind, and as such he needs in-

[2] Prior to the formulation and acceptance of Einstein's theory of relativity, the law of conservation of energy was supplemented by the law of conservation of matter. It is now understood that the latter is merely a special case of the former, for mass and energy are interrelated.

dividuality in his relations with other men. In addition, each of us needs ways to express his individuality and creativity. These very basic needs can be fulfilled by purposeful, goal-oriented, work activity. Even the most menial chores can be challenging and satisfying if they are performed with dignity of the individual in mind. The general tone of the organization must reinforce the firm belief that each individual is unique and human. Management policy and action must encourage the development of each and every man to his full potential. Challenge, understanding, and an adequate sense of responsibility are essential. Each individual must recognize the importance of his accomplishments to himself and his fellow man.

SELF-DETERMINATION

Much of human nature is based upon a desire to know what the future holds. We adjust our behavior to patterns that allow us to have certainty concerning our next few moments, weeks, or years. We learn to avoid behavior that is likely to be painful and frustrating. We strive for behavior that will bring pleasure and satisfaction. Where our interpretation of cause and effect is inaccurate, we become frustrated and upset. We also lose pride, interest, and satisfaction when we have no control over the consequences of our actions. We are unable to predict what will happen to us because we have not had a share in the determination of those things that control our destiny. This situation can be avoided by sharing the responsibility and authority for on-the-job methods and relations with those directly involved. Participation offers a marvelous way to provide self-expression, creativity, challenge, and self-determination in daily work activity. The security of the inner man can be reinforced by participation.

WORK ELIMINATION

All work activity should be purposeful. It should be aimed at goal achievement. The activity should transform the energies and materials in our work system into the most useful products in the most effective manner. The activity should be evaluated in terms of the intangible benefits as well as the physical accomplishments, and all waste should be eliminated.

Each and every sub-part of the work activity should be questioned relative to its contribution in advancing us toward our ultimate objectives. We should question the specific objectives of our individual jobs, processes, and procedures to determine if we are really shooting for the most appropriate objectives, and we should consider alternative objectives relative to our basic business responsibilities. We should also consider alternative ways to achieve our work goals.

The challenge of applying the principle of work elimination is to question all work activity in terms of its contribution to productivity, to eliminate those activities that are not productive (that is, those activities that represent waste), and to devise ways of making necessary work unnecessary so that it may be eliminated.

SMOOTH AND BALANCED FLOW

After all non-productive or unnecessary work has been eliminated from a work system, it is then necessary to determine the most advantageous organization of the necessary work activity. Very simply stated, this means that we should arrange for physical flow that is smooth, balanced, and properly time-phased. All materials, parts, tools, equipment, manpower, and information should be available when needed. Interruptions, interference, delays, and back-tracking should be avoided. Motions of the process and workers should be natural, smooth, and rhythmical. The flow should be regulated to utilize effectively the capacity available within the work system. The skills and abilities of the human component of work systems should be utilized to near capacity.

EFFECTIVENESS

All parts of our work activity should be as effective as possible, consistent with the over-all effectiveness of the work system. Each work step should be evaluated in terms of increasing its effectiveness. We should attempt to accomplish the necessary results for the individual work step as a by-product or combination of other work steps. Each work step should facilitate the other necessary work steps. Where possible, processing of multiple units should be considered and encouraged.

SIMPLICITY AND DIRECTNESS

Each and every part of our over-all work activity should be as simple, logical, and straightforward as possible. Confusion should be minimized. Ineffective skill requirements should be eliminated. Each and every action should be a logical and obvious result of preceding work.

The physical effort required to accomplish work should be minimized. Mechanical aids should be considered to help human performance. Skills should be utilized fully.

STANDARDIZATION AND PRE-PLANNING

After work methods have been analyzed, and improved methods developed, it is advisable to standardize the various factors affecting the work system in order to assure effective operation. Standardization need not be restrictive to the point that individual differences are ignored or further improvement stifled. The objective of standardization is to facilitate effective operation. It provides a base from which further improvements can be developed and evaluated.

Pre-planning implies that the various factors affecting work are standardized and incorporated into a rational plan for work so that good methods are perpetuated and poor work methods prevented. It would be poor economy

to analyze work methods and develop improved ways to accomplish the work, and then not carry on to the point of unifying the improvements so that there is a record explaining and facilitating the use of the improved methods.

Standardization and pre-planning also guard against continuing change that may disrupt and confuse. Change should be encouraged—but only when the results fully justify the associated cost and inconvenience of the change.

QUANTITATIVE EVALUATION

The results of a new work method or improved work system should be evaluated. This evaluation will include the determination of the cost associated with work performance and may also include evaluation of capacity, time, and space requirements for proper performance of the various components of the work system. A normal or standard of performance should be developed for each unit of the system. These standards will allow effective planning for work accomplishment and serve as a basis for evaluation of actual performance.

The principle of standardization and pre-planning, when considered with the principle of quantitative evaluation, results in a complete blueprint for work accomplishment. The requirements for an effective work system, including all of the factors affecting work, have been specified, the required results have been determined, and the quantified evaluation specifies how the system is to perform. This approach is the design approach. Work systems are designed on a functional basis and all aspects of the system are specified.

The design approach to improved work methods is in sharp contrast with the trial and error approaches. Each factor affecting the performance of the work system is carefully considered as a design factor and thus helps in the development of the final design. It is not a mechanistic approach, for human values are directly considered. The human factors of a work system are extremely important, and they are prime factors incorporated in the design. Performance standards for individuals are also important, and they are a vital part of the system design. These performance standards can be developed from standard data, measurement, or estimate. They should allow for individual differences, and their inherent limitation in accuracy and precision must be recognized.

PROPER INSTALLATION

Understanding, agreement, and authorization are important prerequisites to the successful use of any work improvement. Whenever changes are made, the work system is disturbed. The impact of changes can be channeled into constructive veins only when the changes are carefully considered and understood by all those affected. This acceptance and understanding can best be achieved by participation in developing the changes to the extent that the changes actually are originated by the men on the job and their supervisors.

The objectives of the new methods should be very clearly stated so that they are fully understood. The new methods should have full backing from management. New skills should be adequately developed before the new methods can be expected to perform properly.

The phrase "resistance to change" is frequently associated with problems of methods improvements. When change is resisted, there is always a very good reason for this resistance. Resistance to change is actually a symptom of deeper troubles. Uncertainty, lack of understanding, and fear of the consequences of the new method threaten the security of the individuals. The individuals, in turn, try to maintain their inner security by resisting the change. These factors that cause resistance to change can be neutralized by dealing with them directly through the dynamics of developing a desire to change and improve within all individuals in an organization.

THE DYNAMICS OF CHANGE

A continuous evaluation of system performance is essential to adequate maintenance of effective work methods. Change is inevitable. When any of the factors affecting work do change beyond the limits specified in the work system design, these changes must be recognized and appropriate corrective action initiated. In some cases the cause of variation should be corrected so that the factors return to normal. In other cases it may be that a modification of the system is in order. It may be that further improvements can be justified, or that the requirements of the system have changed and obsoleted the current system.

Change is inevitable, but we should take steps to insure that proper changes are made as soon as they are justifiable and that deleterious changes are prevented. This will insure the continued use of optimum work methods and the maximum performance of the work system.

CONCLUSIONS

Jobs can be *designed* so that they are both mechanically efficient and efficient from the standpoint of the dignity of the individuals performing the work. This is accomplished by an enlargement of jobs, leading to job design based upon broad criteria of economic and social desirability. When this is done, both the short range and the long range objectives of an organization can be achieved in an optimum manner.

Productivity without Compromise

The Burden of the Past

by **FRANK H. SQUIRES**

Director of Quality Control, Topp Industries, Inc., Los Angeles

THE conflict between Industrial Engineering and the past epitomizes the profound social-economic changes created by the technological revolution. The technological revolution of the last 50 years has converted the United States from a multitude of relatively simple communities, still living in the historic tradition of much sweat and long hours of manual labor, to an almost toil-free mechanized paradise.

Fifty years ago the first machine tools and some primitive agricultural machinery helped out the numerous manual workers. To-day the remaining manual workers tend machine tools and participate in processes of a complexity and productivity beyond the imagination at the beginning of the century. A flood of manufactured products, of consumer goods and capital goods has been released which has changed every aspect of the American way of life.

INCREASED PRODUCTIVITY

It is the increased productivity, the multiplication of one manual worker into many by improved machine tools and carefully studied manufacturing procedures, that is the most characteristic feature of the change. Who made the studies? Who separated the mental part of every manufacturing operation from the manual and developed the practice of production planning? Who lightened the burden for the manual worker while increasing the productivity of the operation of which he was a part? The reply to these questions is a matter of historical record; it was the Industrial Engineer. The first of these, known to all of you, was Frederick Winslow Taylor. You are all familiar with the classic studies he made on the moving of pig iron and on shovelling a variety of materials in the vast yard of the Bethlehem Steel Company. By observation and experiment, and by taking thought, he increased considerably the productivity of each manual worker.

He should speak for himself as to the benefits of the studies he made. He did this work in the late 19th Century, using two "college men" to help him study what he called the "science of shovelling." He built an office in the yard where each laborer's work was planned a day in advance, and where clerks worked all night to compute each laborer's earnings. Each shoveller then knew at the beginning of the day how much he had earned by following instructions the previous day.

In the first decade of the 20th Century, many factories made such studies to increase productivity. Strikes occurred at a number of plants where the manual operators complained against the alleged "speed up." The strikes led to a congressional inquiry and on January 25, 1912, Taylor found himself before a Special House Committee.

He said, "When we went to the Bethlehem Steel Company, we found 400 to 600 men at work in that yard, and when we got through 140 men were doing the work of the 400 to 600." Since that time we have developed mechanical shovels and the productivity of the machine and the manual operator has been multiplied many times beyond Taylor's improvement. It must be remembered that the 140 laborers whose productivity was increased from three to four times, were still using shovels although they were special shovels selected by Taylor for different materials. But Taylor's approach and the approach of the men who designed the mechanical shovel were still the same, a recognition and acceptance of the rational discipline of thought before action.

Taylor (2) went on to say,

> We were very fortunate to be able to get accurate statistics as to the cost of handling a ton of materials in that yard under the old system and under the new. Under the old system the cost of handling a ton of materials had been running between 7 and 8 cents, and all you gentlemen familiar with railroad work know that this is a low figure for handling materials. Now, after paying for all the clerical work which was necessary under the new system for the time study and the teachers, for building and running the labor office and the implement room, for constructing a telephone system for moving men about the yard, for a great variety of duties not performed under the old system, after paying for all these things incident to the development of the science of shovelling and managing the men the new way, and including the wages of the workmen, the cost of handling a ton of material was brought down from between 7 and 8 cents to between 3 and 4 cents, and the actual saving during the last six months of the three and one-half years I was there, was at the rate of $78,000.00 a year. That is what the company got out of it; while the men who were on the labor gang received an average of 60% more wages than their brothers got or could get anywhere around that part of the country. And none of them were overworked, for it is no part of scientific management ever to overwork any man.

Gilbreth, a contemporary of Taylor, made time and motion studies on bricklaying. His recommendations resulted in what were probably the most radical changes in this basic trade in 4000 years. He reduced the number of motions required to lay a brick from 18 to 5 and increased the number of bricks laid per hour from 120 to 350 (1).

Many Industrial Engineers have followed in the footsteps of Taylor and Gilbreth, and tens of thousands of studies have been made on every possible kind of industrial process. Always the productivity, the rate of produc-

tion has been increased. Furthermore, since each of these studies identified the contribution made by the artisan and recorded it on a production process sheet, traditional skills which had come down from journeyman to apprentice through many generations were made available to all. Not only was the productivity of a particular operation increased but the possibility of an absolute increase in over-all production was made possible by the ability to take and apply the written procedures wherever there were machines, or other means of fabrication, and men willing to learn.

Now the most important thing to recognize in time and motion study, or in scientific management as F. W. Taylor called it, or in Industrial Engineering as we now call it, is that it requires men to stand aside and observe and to take thought on what they see. Since the great material wealth they have helped create is a matter of record in the United States and of wonderment throughout the world, it can be concluded that Industrial Engineering is a major production force and is universally recognized as such.

A BURDEN?

There is one sure guide to industry's evaluation of the essential character of the work performed by a man or a function, and that is the cost accounting designation. Industrial Engineers are designated "indirect." This doesn't sound very disparaging even when contrasted with the classification "direct," applied by cost accountants to production operators who "change" the product.

It might be thought that the labels "direct" and "indirect" were meant only to distinguish between the manual and mental parts of production and there must be many who use them in this belief. However, there are other parallel terms which are frequently substituted for "direct" and "indirect." Most revealing are the classifications "productive" and "non-productive." In these two designations the distinction is drawn with brutal frankness and nothing needs to be added to such a startlingly unambiguous separation of those who produce from those who don't.

Something is added, nevertheless, and those who have already been condemned as "indirect" or "non-productive" are further disparaged as "overhead" and "burden." These discriminatory distinctions are more than accounting designations, they are indicative of a state of mind shared by many other than cost accountants. "Indirect," "non-productive," "overhead," or "burden," all mean parasite. It would be possible to use the more polite term, beneficiary, but good manners would not remove the obvious implication.

Before inquiring why the disciples of Frederick Winslow Taylor have been rewarded for their magnificent contribution to production in such an astounding manner, one ought to make sure that the terms "indirect," etc., carry their full disparaging meaning in common daily usage.

Managers from coast to coast apply a test of unmistakable meaning. It is the commonly accepted measure of management efficiency, the ratio of indirect costs to direct costs. To be considered efficient a manager must keep the ratio low. He must carry few indirect personnel in relation to direct and no matter how few he has he must constantly strive to make them less.

The tendency to compute plant productivity in relation to manual operators only, and not to the entire payroll, is another outcome of the basic assumption incorporated in the cost accounting system.

Taylor had to face this problem at the turn of the century and his testimony makes it clear that he considered the staff men who made the study, the clerks who did the production planning, the earnings computers and the manual laborers, as one production force. The number of shovellers was reduced from approximately 500 to 140 or by 70%; the cost of shovelling was reduced from an average of 6 cents a ton to 3½ cents, or by 40%.

To a forthright man like Taylor, the cut in the over-all cost of handling material by 40% was the only standard by which the success of his effort could be measured. Not for one moment would Taylor have accepted the argument that the cost should have been cut by 70% because the manual labor force had been cut by 70%; he did not consider the manual laborers the only producers.

THE MANAGER

Tayor's experiment in observation, analysis and planning, and its substantial success could be embarrassing to a modern manager. The manager is professedly judged on his contribution to the profits made by the company as a whole. In practice, it is frequently difficult to isolate his effort from the many complex interacting factors which make up the whole and he is, therefore, judged by the traditional indirect/direct ratio. There are other measures by which he is judged but this is by far the most important.

The manager, therefore, being in charge of a mixed production department, hires a handful of Industrial Engineers. They observe, make notes, take thought, and grind out new production methods and procedures. The over-all productivity is increased by 40% and the "direct" labor force is decreased from 500 to 140.

This creates a problem for the manager. The efficiency ratio has been drastically changed. Not only has the denominator been reduced from 500 to 140 but the small group of Industrial Engineers in the numerator, relatively small when compared with 500, has become monstrously large in comparison with 140. The manager is going to have to cut deep into the "overhead" to restore his efficiency ratio. First to go will be the Industrial Engineers, despite their earnest and pitiful protests that they ought to be kept on to monitor the new production procedures and to make further studies!

It is not suggested that the current generation of cost accountants originated this archaic terminology, or that they perpetuate its use just to obstruct the application of thoughtful analysis to industrial operations. Nor is it suggested that its continued use is meant to delay the forward march of the technological revolution in the United States. Nevertheless, it tends to have this effect.

SUMMARY

Why do we persist in the use of a cost accounting system based on the assumption that only manual labor is productive when we have known for fifty years that this is no longer true? We all know that the contribution to production made by "direct" manual labor is a constantly diminishing fraction of the whole because we study cost breakdowns every day. Production "direct" manual labor is no more than 10 to 20% of total manufacturing costs, depending on the industry. In 1956 for the first time in history, the number of white collar workers (engineers, analysts, clerks) exceeded the number of manual workers employed in US industry. Are we going to assume that this vast army of "indirect," "non-productive" individuals has come into existence only because incompetent managers failed to cut back the proliferating "burden"? Or are we going to acknowledge that these are the creators of the technological age and recognize them as such in a revised cost accounting terminology?

We have to look far back into history, when our cultural standards were being formed, to find the origin of the belief that only manual labor is productive. It is certain that food, swords, buildings and clothes were all produced by manual labor but however far one goes back in history some planning was necessary. Someone had to decide which slope of the hill to grow the grapes on; someone had to decide where to build the village which in time would become a city; someone had to design weapons before they were hammered into shape.

It would have been possible for the planners and the designers to have made claim to a large part of the productive effort, yet the historical record does not show that such claims were made.

Perhaps men have always tried to avoid hard manual labor, both because it is physically exhausting but even more so because the manual worker had low social status in the hierarchies of the past. A man of standing in the community could plan and he could design, and it would be known he was not a manual worker. When it became necessary to identify the manual worker as a producer then the man of standing, the planner, the designer, refused the designation "producer" to avoid identification with those who tilled the soil and hammered metal.

The irony is that designations which are derived culturally from the aristocratic beneficiaries of earlier social systems have become a constant jeopardy to those so designated in the modern age.

Cost accounting designations must be rationalized to permit the employment and utilization of Industrial Engineers and other non-manual technical personnel on a positive basis instead of on a basis of tolerance and sufferance.

The burden of the past, equally onerous to cost accountants as to Industrial Engineers, must be removed to permit the fulfilment of the tremendous potential for increased productivity in the new technology.

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Productivity Through Quality

by **W. GRANT IRESON**

Professor of Industrial Engineering, Stanford University

ANY organization can increase its output by adding people, buildings and tools, but the real challenge to Industrial Engineers is to increase production with existing human and physical capacities. My thesis is that through attention to quality and quality functions, the productivity of any organization can be increased.

Quality mindedness and quality control affect productivity in a number of ways and in many locations within the plant. Instead of dwelling on the fundamental quality control concepts and tools I am going to discuss the contribution that quality control personnel can make in the design, engineering, manufacturing, assembly and final testing of products.

In order to get a setting for this discussion, let's assume that we are dealing with one of the typical small or medium sized electronic firms that are so numerous on the west coast. This firm has a large (relatively) staff of top quality electronic and mechanical engineers who are developing new systems for accomplishing any number of different objectives. The company is proud of its original design work and enjoys a reputation for turning out reliable products. It has a small quality control department that is essentially "staff" in nature. Inspection of product on the line and final checkout of systems is done by persons who report to production management. Quality control is responsible for receiving inspection and acceptance, for approving all components (purchased or manufactured) issued to production, and maintains quality records.

Since this company is essentially a development company, its production runs are usually of only 50 to 100 systems. Each system may contain 10 to 15 different "black boxes." In addition, the production run may be broken up into two or three different production orders.

You see immediately that this is the kind of a company in which people say, "We can't have in-process control because our runs are too short." This doesn't mean, however, that there is not a real job for quality control, or that quality control should be relegated to a minor role. Let's follow through the design, engineering, production and assembly of a typical system, and find out where quality control should enter into the picture.

The design engineers are given the general function specifications for a new system. They then design the new system (including the determinations of the "black boxes" required) on paper and check it out mathematically. Then, they build up a "bread board" model of the subsystems and the entire system. These models are made of components drawn from the engineering stock room or production stock rooms. As they check out the performance characteristics they find that some components must be changed, or swapped for components of other values. Sometimes, I have observed, one component of a given nominal value will work properly while another of the same nominal value will not. This points out the first instance where "quality mindedness" should come into the picture.

QUALITY MINDEDNESS

A large number of the design engineers are perfectly aware of the fact that the values of the electrical characteristics vary, and that components cannot be made to exact specifications, but they fail to take this into consideration when they specify the components to be used in the production model. The components that were used in the bread board model probably varied from their nominal values by 2%, 4% or even 10%. The engineers are likely to measure the exact value of a resistance or capacitance, and then specify that value, with some small tolerance, such as $\pm 1\%$, without really knowing whether this is necessary or not. This practice makes untold trouble for the production engineering staff, the production department, and purchasing, to say nothing of the increased cost of components that result from the tight tolerances.

Quality control should have two major functions at the design stage. It should be responsible for some training or indoctrination of the design engineers regarding the basic variability of components and assemblies, so that the designers will recognize the need for going a bit farther than just determining that a design built with specific components will perform properly. Secondly, the quality control personnel should be allowed to review designs and specifications before they are released, so that potential trouble spots can be recognized and possibly corrected at the design stage. At worst, the quality control persons will know that specific instructions will have to be given to purchasing, manufacturing, and assembly, so that the potential trouble spots will not become major bottle necks.

PRODUCTION ENGINEERING

Next the design goes to the production or manufacturing engineering department where it will be reduced to factory working papers. These engineers will determine just how and where to mount each component, the wiring diagrams, connectors, chassis, etc., and prepare the necessary working papers. A model will have to be built at this point to prove the manufacturing design, and very likely the physical rearrangement of components will cause interactions that were not present in the breadboard model. Frequently this is a serious matter, and specifications on components and even circuits may have to be changed in order to obtain the desired functional characteristics. The amount of variation that can be permitted in the components may be either reduced or increased by the "packaging" arrangement of the unit.

Here, again, the quality control concepts should be kept in mind by the production engineers. They should be aware of the problems of variation of both individual components and interactions. They can build up a working knowledge of interactions so that results can be predicted, provided they take the trouble to record effects and to review the records to see how patterns of variation develop. For instance, the distance between certain kinds of components and conductors affects the interaction, and experience can be recorded to enable the engineers to predict the results of a specific design. Quality Control can assist in setting up the records and in analyzing the results.

Similarly, the production engineering drawings, assembly diagrams, instruction sheets, and models should be reviewed by quality control so that suggestions can be made early in the procedure to avoid undue difficulties. For example, the assembly operations are not all of equal difficulty nor of equal importance. Determination of the quality characteristics that should be checked by the line inspectors should be made at this point. Special instructions for assemblers and inspectors should be prepared so that they will know what is important and where special care must be exerted. Unless quality control is brought into this activity there will be mistakes that will delay production and will cause a large amount of rework.

PURCHASING DEPARTMENTS

The purchasing department is often put in a very undesirable position by the design and production engineers as a result of specification. Many companies purchase commercial grade resistors, capacitors, transistors and the like, and then sort them into bins according to their electrical characteristic values. Thus, 100 ohm resistors, with a commercial tolerance of $\pm 5\%$, may be sorted automatically into bins with 2 ohm intervals. Now, if the engineers specify a resistor of 96 ohms, ± 1, it will not be a commercial grade, and does not fit into the sorting system used. This should have been avoided first, by having quality control check the original specifications. How-

ever, if the purchasing agent trys to buy the specified resistor, he is going to have to pay a premium price if he gets it at all, and may not find a manufacturer who is willing to quote a price or supply it. Quality control, if it has adequate records of the incoming resistors from various manufacturers can tell the purchasing department what it can expect, and what the relative costs would be of buying commercial grades and sorting them to obtain the desired values. Materials control should be able to tell the purchasing department what the probability is that commercial grade resistors encompassing this specified one will be needed in other devices.

Even when there is no problem of special specifications, the purchasing department should depend upon the quality control department to provide it with basic information about the reliability of the various sources of components. This vendor verification or source selection activity is logically a function of that department that inspects the incoming materials for acceptance purposes.

Also, the quality control department should make the puchasing personnel aware of the necessity for clear and meaningful specifications and purchasing agreements. It is a common experience for the quality control department to receive a shipment of materials and find that some of the specifications are so written that the characteristics that were considered important cannot be checked or tested. Quality mindedness on the part of purchasing agents will help to eliminate such occurrences that increase the cost of materials as well as delay their acceptance. Sometimes materials will be held for weeks while engineering and quality control try to devise means of testing for some given property or decide that it can be ignored.

PRODUCTION SUPERVISION

The production areas present special problems, but are more familiar to most of us. The common practice of having line inspectors report to production supervision means that quality control has very little opportunity to get the records that are necessary to the maintenance of a high quality level. Because the production supervision is primarily interested in output, it seldom agrees to having the inspectors do more than record the number of units inspected and the number rejected in a given period of time. This is information for a p chart, which certainly tells something, but often the information is not from one universe or population, and it becomes almost worthless, except as an over-all measure of the quality of the production line.

In many companies the electronic devices will receive one or two visual checks during the assembly operations, and only when the unit is complete will it receive an electrical or "hot" check for both continuity and performance. Usually the inspector does not have time to determine the cause of malfunction, so that the reject units are sent to a special area where highly skilled technicians make the diagnosis and send the units to the rework department. Eventually the reworked unit will go back to the same inspector. The rework may have corrected one fault but produced another one. The same unit may pass the same final inspector several times, being recorded as a reject each time. The quality history is distorted, and attempts to compare day-to-day operations are almost completely meaningless.

PREVENTION

One of the duties of quality control is to prevent the manufacture of defective units. However, in this short run industry, where inspection is performed as a production function, quality control seldom gets the information necessary to pin point the actual causes of defective material. Part of this is due to the close personal relations between production personnel on the same line, and part is due to the fact that a run may have been completed and gone before the quality control man knows that it is in production. This may not be too bad, providing that every production order is for something entirely new and different. I have not, however, found a plant in which there are not some basic and fundamental similarities of the units from day-to-day and week-to-week. Failure to recognize and to capitalize on these similarities prevents the quality control department from being able to measure the variation in the quality of work from day to day and keeps it from being able to decide when something should be done on the production line to correct the causes of a high defect rate.

Carelessness in soldering, mistakes in wiring, poor workmanship, and sloppy work, in general, can be traced to individuals. Some are more prone to it than others. Quality control has the responsibility of locating these people through its information system, and of training them so that they become quality minded. Even when these production people are working on different kinds of jobs each day, the quality control concepts can be applied by production areas, types of work or production groups, and if the information system is set up properly, it will tell the quality control man when there is need of corrective action.

INSPECTION EQUIPMENT

Quality mindedness should be extended to cover the instrumentation on the production lines and in the receiving areas. There is a big quality control job to be done in maintaining the calibration of test and inspection equipment. No one else in the organization is in a better position or better prepared to do this than quality control. It is axiomatic that quality can never be any better than the accuracy of the instruments, yet we will see, day-after-day, inspectors trying to decide whether to accept or reject a unit with an instrument that is not as accurate as the unit being tested.

Recently I saw a young lady testing a precise unit on

which the specification called for ±.2 db. The instrument she was using had a scale on which the smallest division was .5 db, and was only about ⅛" in length. There was no mirror behind the needle. Also, I noticed an inspector trying to accept resistors whose specification was 100 ohms ±1%, using an instrument on which the smallest reading he could make accurately was 5 ohms. I think it is needless to say that the results were anything but reliable in both these instances.

EXCESSIVE COSTS

Due to the failure of the designer to determine the operating range of a certain component, it was necessary for the inspectors to sort through over 1,000 $6 components to find 50 that were about 2 standard deviations above the nominal value. The instruments proved to be barely adequate for the purpose provided the inspector was especially careful. This could have been avoided by changing the specified value of a 40 cent component in the assembly. The trouble was that the 40 cent component had been potted along with some 10 or 11 other components before it was discovered that the $6 component would be so critical.

I have had top management men tell me that they cannot afford more than a minimum quality control effort. I contend that they cannot afford to have anything less than an adequate quality control staff to analyze, solve and implement the kinds of problems that I have been discussing. A company that was generating defective electronic units three times as fast as their twelve-man diagnostic team and 23 man rework department could correct had to accumulate a quarter of a million dollars worth of reject parts and units in its rework department before it decided that quality control should be strengthened and given a relatively free hand in the prevention of the more defectives.

SUMMARY

Quality control concepts are applicable to every phase of a manufacturer's operations from product design, through production engineering, parts manufacture, assembly, inspection, test, packaging and shipping.

Reliability of the final part depends upon the proper design and the proper manufacture of the units. Quality control should be consulted during the design stage to avoid costly errors, and should be the guardian of quality throughout the remaining manufacturing and assembly stages. Quality control should be independent of both engineering and production, answering to the same level as these two organizational groups. Engineering, production and quality control should constitute a team, working together for the common objective: a reliable product at the minimum cost.

Attention to quality does not mean that every activity of the quality control group will involve massive statistics, elaborate equations, and statistical gobbledygook. An effective quality control program will deal more with organization, procedures, data collection and analysis and quality mindedness than it will with pure statistics. Attention to quality will identify those areas or problems that need consideration, and will avoid useless effort on satisfactory areas.

Finally, quality control can eliminate or reduce many of the restrictions on high productivity, and assist materially in increasing the output of acceptable product with the same personnel and capital investment.

The Quest for Certainty

by **ADAM ABRUZZI***

Professor of Industrial Engineering, Stevens Institute of Technology

"SCIENTIFIC MANAGEMENT" and Industrial Engineering germinated in an intellectual climate in which there was reason to believe that man's quest for certainty was shortly to be crowned by success. The late nineteenth century inherited an impressive array of triumphs in the physical and biological sciences; the universe and all its works seemed to be standing by waiting to be understood, and understanding was to be achieved by the seemingly straightforward device of subdividing and conquering. With patience the keynote, progress would be continuous and swift toward the Utopia of complete understanding.

This view, with its full armor of a deterministic philosophy, which implies that things are fixed and immutable, was hungrily taken up by the behavioral disciplines. Most investigators in the behavioral areas eagerly grasped at the vision that a deterministic approach would yield the answers to their problems. Thus it was that there arose theories of "scientific" sociologies, and a number of others, each promising a cornucopia of once-and-for-all results in the realm of human behavior.

The situation was not altogether one-sided. There was William James, for one, who felt that insights, arts and decision-making under uncertain conditions were fundamental and elegant ingredients of human behavior, nonsusceptible to deterministic probing.

It was in this setting that the "scientific management" revolution came into being. The essential views held here were the same as in other fields; the perfect factory would be the factory conceived and run on rigorous scientific principles and equally rigorous technological apparatus. The theme again was determinism; the procedure again was subdivide and conquer.

THE ACHIEVEMENT OF CERTAINTY?

The triumphs of the deterministic approach continued until, in mathematics, a crisis appeared early in the twentieth century. This crisis was only resolved by ruling out certain classes of questions as being meaningless. This

* Some of the concepts considered in this paper were developed with the aid of a Guggenhiem Fellowship for 1956-57.

did not relieve the situation for, several years ago, a celebrated theorem (by Godel) proved there were infinitely many questions in mathematics that could never be solved by mathematics.

The deterministic approach also began to crumble in physics, even in the aggregate or macroscopic domain. It was Einstein's genius that resolved the crisis, and he did this by showing that what we observe is a function of the observation system. (Einstein spent the rest of his life valiantly trying to undo what he did here and to restore determinism to this and other domains of physics.)

In the individualistic or microscopic domain the disaster was even more devastating. Elementary particles were found to obey, not deterministic laws, but only probability laws, and these only when special rules were constructed. Things were no longer thus-and-so; they were just likely to be thus-and-so. A reprieve was thus obtained through the invention of probability theory, and this made possible a new and softer determinism, the determinism of probability. Things were no longer related by determinate cause-and-effect relations, but rather by probabilistic relationships, with no clear-cut way to define cause and effect.

Despite this reprieve new crises developed before too long, especially in the microscopic domain. There is the principle of uncertainty which states that certain things are *forever* unknowable about individual particles, such as electrons; there is the principle of complementarity which states that things may behave, i.e., exhibit, themselves in different forms at different times; there is the principle of what might be called historical asymmetry which states that, to know about something now, we must give up some knowledge as to what it might have been.

Then, too, there are the anomalies, which seem to come out of a child's science fairybook; these anomalies make it necessary to postulate particles without mass but with spin, and a new "ether" which takes on different properties in response to environmental commands. Despite this series of conceptual explosions in physics, the other physical sciences proceeded to work along classical lines, mostly with success and generally at the macroscopic level. But chemistry, for one, ran into some of the same crises, and it was forced to ally itself with quantum physics in a common defense against the crumbling of a deterministic universe.

Behavioral scientists—too many of them—reacted to these developments in a perhaps not too surprising manner: they selected out what they liked and understood but refused to see—or couldn't—what the crises really meant. What happened was that the soft determinism of probability was quickly gobbled up, along with some other patch-up devices of the physical sciences. With these, there began a somewhat hectic hunt for complete theories of man and his personality, both for man as individual man, a unity which stubbornly refuses to be microscopic, and for man in the group, the human collective whose units can seemingly be induced to act microscopic.

This has proved most contagious and there is now a massive attack on ignorance in all domains of human activity. The goal is understanding through technique; technique is the order of the day in schools, homes, barns, bars, factories and universities. Yet though it is understanding that is so earnestly sought, it is precisely understanding which is not being found.

Understanding seems to be considered a process of doggedly chasing down ignorance. According to this view, achieving understanding is like achieving virtue. In what becomes a grim struggle, ignorance must be rooted out and exposed, for only then can understanding triumph.

THE WORLD OF INDUSTRIAL ENGINEERING

The field of Industrial Engineering has not been immune to this approach to understanding. There still is a stubborn view, though it is not nearly as universal as once it was, that Industrial Engineering is a science. There is reason for this. The field was nurtured in an era of an imperious determinism; this was also an era in which industry needed rationalization for further development.

It wasn't long before Industrial Engineers discovered that the world of the factory did not yield easily to the presumably scientific precepts of time study and wage incentive systems and, later, to the rational precepts of job evaluation, merit rating, and so many others. Then, as now, this was generally attributed to irrational behavior, most often that of workers. F. W. Taylor, for example, could not understand why workers found it in their interest to respond to time study standards by withholding production.

Such views are perhaps understandable in Taylor's case; those who formulate new theories—and Taylor was, among other things, a theorist in moral philosophy—seem to be carried away by their own inventions. This is why they tend to consider as aberrations any activity which their theories cannot explain. It would be neither gallant nor logical to consider Taylor's view to be irrational. Taylor had to be as loyal to his theory as the workers were to their's. What happened is that there was a clash of theories, the workers developing a counter-theory to protect themselves against Taylor's theory.

Most Industrial Engineers are by now perfectly aware that things didn't work out according to their scientific or, more properly, rational precepts. Things did work according to precept but there always appears a kind of *deus ex machina* which works in reverse. Rational precepts in application generate counter-precepts, with the result that the process of application ends up as an equilibrium of opposing forces. The road to a rational Utopia, it seems, always doubles back on itself, and the endpoint is somewhere near its midpoint. Thus it is that workers will respond to wage incentive plans to a point, but they will then put their responses in reverse gear, so to speak,

so as not to exceed that point. (Parenthetically, this seems a behavioral imperative regardless of geography or creed; the incentive norm of about 130 percent (of production standards) is common to both American and Russian workers.)

Practicing Industrial Engineers, like most everyone else, operate under the intellectual, and perhaps also moral, imperative that reason should prevail. This is why most of them still consider processes of accommodation to be the result of irrational behavior. A minority of diehard zealots go further and believe that such behavior can and must be chased down and purged. Classically this has usually been attempted by means of economic and moral pressures. Nowadays such pressures are supplemented, and perhaps even supplanted in large part, by nudges toward conformity; all these take on a variety of forms and have varying degrees of intensity, depending on the immediate "irrational" situation.

The result, generally, is that the "irrational" behavior is only pushed beneath the surface and hidden from view. Most Industrial Engineers know, however, that this is only a shadow victory; they have learned that "irrational" behavior is here to stay. They are not only prepared to concede this, but they recognize that they cannot be successful unless they understand such behavior and learn how to deal with it in practical terms. They know the successful Industrial Engineer is not the one that invents the best rating system; rather he is the one who knows how to adapt *any* rating system to real situations.

This is why it is just the observer who views things through rational lenses who is perplexed by the seemingly irrational fact that different rating systems, each developed to plug leaks in earlier systems, can not only coexist, but flourish, side by side. The insightful observer who views things through the lenses of experience and empathy sees this to be a perfectely logical situation: it is logical, when there are conflicting goals and interests, that it should be skill in application that counts, not rational perfection.

What Industrial Engineers have come to understand, then, is that theirs is a field requiring an intimate blend between rational systems and accommodation processes within a rational framework. The blend must yield an equilibrium result acceptable to two or more groups. This is needed to maintain a stable relation between groups which begin by having conflicting goals and interests, each with their own logic. The equilibrium result refines an area in which the conflicting goals and interests can be made to intersect rather than just collide.

THE LITERATURE OF INDUSTRIAL ENGINEERING

The accommodation processes in what might well be called the underworld of the factory are not easily amenable to formal description. Expression here is a matter of art, not science; a matter of insight, not reason; a matter of empathy, not detachment; a matter of feeling, color, tone, and texture, not of reading pointers, meters, and formulas.

There is a prolific and contagious confusion on the subject. Most scholars shun such things as being perhaps unworthy of intellectual inquiry, though it appears that this self-ostracism is because accommodation processes refuse to be fitted into theories, theorems, and axioms.

Thus there is a kind of cause-and-effect relation between difficulty of expression and the scholar's imperative to put things in rational form, a relation which is itself based on an accommodation process. One outcome of this is that the literature of Industrial Engineering has, in the main, side-stepped all but the rational aspects of the subject. Since rational things are so often moral things where human interests are involved, the literature preaches morals while laying down rules. Rules are proposed because they are rational and, therefore, they ought to be followed. (It is difficult indeed to find the points of origin here; it appears that morality often precedes reason and what ought to be is first decided and then labeled rational.)

Industrial Engineering is not exceptional in this respect for, as the insight-rich Thurman Arnold shows, the literature of economics and the law has done much the same thing. But Industrial Engineering is fairly exceptional in that it must deal with living practices in a real world where goals and interests exhibit complicated patterns of collision and contact.

To abstract from this world a set of rational rules is to design an upperworld whose structure, considered by itself, eventually reduces to fairly sterile prescriptions. The rules are readily seen to represent something other than what people really do and, because of this, must have strong moral tones so that people might be persuaded that this is what they really ought to be doing. This must not appear too obvious, however, so that the rules are stated in the grimly pious terms one comes to expect of rational statements and moral statements alike. Whatever else might come of being reasonable and moral, it seems safe to say that the process does not provoke excitement.

The notion of a "normal worker" falls in this category in much the same way as the notion of the "economic man." In both, a rational abstraction is constructed to convey the impression that some ideal is involved. But at least with the "normal worker," the ideal is hauled back to earth by attempting to give it flesh-and-blood content. A "normal worker" thus becomes a worker made up of certain appendages and attitudes, all to be weighed on scales and balances.

This creates a babel of bewilderment and confusion. Ideals are essential whenever human interests are in conflict; ideals make up the creeds which identify goals and interests in such a way that people will publicly proclaim them and perhaps even fight for them. It is a blunder to

confuse creeds with practices, and for many reasons. Foremost perhaps is this: creeds should have permanence and universality while practices must be transitory and local.

Under the "normal worker" concept, practices differ so much that creed and practice have produced a mongrel result. There are as many different concepts of the "normal" worker as there are rating systems; and the consequence is endless bickering and dickering over whether this factor is more important than that one. This tends to vulgarize both creed and practice so that there is neither faith in the creed nor confidence in the practice.

The end-product has been a literature describing an upperworld of rational and also moral rules and definitions, generally sterile and often vulgarized because of the unnatural intermixing of creed and practice. It is the factory underworld that determines operating practices and this leaves the upperworld, which is what is written about, very little content.

This helps explain why it is that, until quite recently, Industrial Engineering was not granted a high place in the intellectual hierarchy. Even Thorstein Veblen who was overawed by engineers—and he presumably had Industrial Engineers largely in mind—would never have permitted the subject to be taught in a university.

This also helps explain why there has been much criticism of the *literature* of Industrial Engineers, sometimes from the inside but more often from the outside. One has little difficulty showing, for example, that rating systems developed to implement the notion of the "normal worker" fail to be scientific as proclaimed.

They couldn't possibly be scientific right from the beginning. They represent a set of normative judgments, albeit disguised in the form of numbers and formulas, and their usefulness depends on how well the process of accommodation is carried out in the factory underworld. They represent an attempt to pin down a creed, a creed on what workers ought to do. The result is an almost incalculable amount of effort expended in proving again and again what must be true: rating systems fail to be scientific.

APPRAISAL AND REAPPRAISAL

Despite its literature Industrial Engineering has recently come to achieve a measure of intellectual respectability. One of the chief reasons is that there have been in recent years some successful attempts to bring out into the open the factory underworld and what this implies in various areas of industrial activity. But the newly-won respectability is more largely the result of the ability to apply certain mathematical techniques to factory problems.

It is not too often recognized that it was Industrial Engineers who brought the factory system to the point where this is possible. Indeed, many specific mathematical techniques, such as in sequencing (scheduling) theory, inventory theory, replacement theory, and maintenance theory, were only developed when practical conditions were created which are favorable to the use of these techniques. The techniques, it might well be noted, have not succeeded in solving certain fundamental problems, for example, in production scheduling, even in an abstract sense. This should stimulate an even greater awareness of the subtleties of Industrial Engineering, both inside and outside the field.

There can be no doubt that the impressive array of mathematical techniques, together with their experimental ally, simulation techniques, can be invaluable to Industrial Engineers. This is not because they can expect to solve most of their problems by using such techniques. Such an expectation would be as heady as it is unrealistic and, like most heady things, might well leave a bitter aftertaste. The result could well be a pendulum-swing in which buoyant expectation is replaced by despairing disenchantment.

What can be expected is that these techniques will, in providing solutions for abstract situations, yield insights into the nature of real situations and the paths practical solutions might take. It can also be expected that these techniques, though quantitative in nature, will suggest useful qualitative frameworks for examining problems which cannot readily be put in quantitative form. The theory of games comes to mind as providing a suggestive way of formulating problems in labor-management relations, such as in bargaining and arbitration processes.

These techniques never provide full solutions, even with problems where they are applied in full. All of them require model construction and data-gathering; this requires the skillful formulation of the problem. All of them make simplifying assumptions; this requires a skillful interpretation of the result. All of them must exclude certain non-quantifiable variables, such as human accommodation patterns; these require insights into the application of the result.

This means that the Industrial Engineering profession must develop a comprehensive program of reappraising its problems.

It will no longer be sufficient to accept the fact that there is a factory underworld to go along with a factory upperworld. The reappraisal must go far beyond this. The reappraisal must look into why it is that rational schemes which attempt to exercise tight domination of the factory yield dismal production results, such as in slave labor camps. The reappraisal must, to complement this, look into why rational schemes which provide a certain margin for workers to develop their arts and skills yield superior production results. This suggests, among other things, that a potentially rich area of study is comparative factory systems in diverse cultures.

The factory underworld is thus clearly not only a fact of life to be lived with; it is a fact of life which can lead to exciting explorations into the deep and subtle proc-

esses involved in factory activity. Understanding here would not only lead to an enrichment of knowledge; but it should help pinpoint the imperatives of the accommodation processes used.

INQUIRY AS PARTICIPATION

In some cases the results of accommodation processes are known to some extent, such as the by now legendary success story of the foreman who understands the needs of his workers. What is not well known is the mechanism he uses to achieve this. That mechanism, it turns out, is the mechanism of revealing himself in a form the workers can understand. The process of revelation, unlike the process of observation, cannot be one-sided so that, in the very act of self-revelation, the foreman induces the workers to reveal themselves.

Understanding then, is impossible unless it is two-sided. What is withholding of production, after all, but an attempt not to reveal what workers can do because of the fear that the revelation will harm them? What seems needed is a two-sided process wherein both parties to an accommodation process are given a full opportunity to reveal themselves. One of the chief functions of the rational systems is exactly that: to provide an optional opportunity for mutual revelation.

The point is that, in dealing with the world of the factory, there are not only random variables, but also purposive variables. Human behavior is purposive and, thus, it must be viewed in terms of purposes, interests, and direction. Physical things, on the other hand, are not considered distinguished enough to be purposive and, thus, they are not viewed in terms of purposes, interests, and direction. Their behavior can, with this, be defined as aimless, disinterested, and directionless, for which the appropriate scientific term is random behavior.

Such satisfying views about physical things, it might be added, are now being shaken, in particular, by the uncertainty principle. This appears to be due to the intervention of the observer with his cumbersome apparatus bias. The uncertainty the physicist feels seems to be due not to the electron but to his seeing himself at work. The physicist thus finds himself in the disconcerting position of a photographer who discovers that if he wants a fairly sharp picture, he must always be in it, and what's equally disconcerting, that if he attempts to keep himself out of the picture, there is little, if any, picture left.

There is a fundamental lesson to be learned from the foreman and the physicist. The lesson is that, to induce a revelation of deep things, the observer must himself consent to being observed, i.e., he must become a part of the process of observation. Also, the kind of revelation induced depends on the kind of revelation given so that the process of observation here obeys the principle of what might be called the conservation of revelations.

The Industrial Engineer must face up to the fact that what he is observing is as purposive as he is and, for him, the process of observation is doubly "uncertain." He must face up to the fact that, for him, to observe means also to accommodate and reveal. This is really what the uncertainty principle says. A. S. Eddington puts the matter provocatively; he remarks that an addition to truth can only be won at the expense of an addition to ignorance.

It is a commonplace of the times to believe that this can be accomplished by "selling oneself." All this will accomplish, however, is to prompt the groups one deals with to "sell themselves," with no one really understanding anyone else.

No person or group will reveal their more elegant and, hence, deeper set of values in exchange for salesmanship or—to use a term coming into fashion—gamesmanship. Those holding elegant values know that this is what makes them not only distinguished but also vulnerable. They will reveal them only when there is a counterpart commitment which minimizes their vulnerability.

The situation seems to reduce to this. The scientific study of man is possible only because the things which are readily revealed change from one group to another. To understand the things which are not readily revealed, and which also change from one group to another, requires insight and participation.

This is another reason why the Industrial Engineer must be both an observer with a scientific outlook and a participant with an insightful inlook. Only in this manner will he be able to study the structure of values which characterize the groups with which he deals.

THE CULT OF EFFICIENCY

Views acquire substance by referring them to specific and contrasting things. The specific and contrasting things to be considered here are work measurement and job evaluation. The field of work measurement, nurtured as it was in an era of determinism, has generally been considered to be fundamentally scientific. Latterly, there has been a certain softening of attitude so that it is sometimes conceded, mostly in private, that work measurement is more a matter of reason rather than science.

This attitude, even in the softened form, has been used to justify the tenaciously-held view that work measurement is an exclusive prerogative of management and its representatives. The belief, presumably, is that rational things, such as work measurement, are matters to be settled by experts; it is this belief that ultimately characterizes the cult of efficiency.

This belief, together with the elaborate apparatus constructed so as to give it the appearance of validity, has generated certain counter-beliefs. The result is that there has been, as in all other areas involving conflicting goals and interests, a process of accommodation. This process of accommodation has been described elsewhere by the writer, and only its salient features need to be reviewed here.

The beliefs of management and labor in this area are

polar beliefs, with one set of beliefs implying the complete denial of the others. This has had a decisive effect on the manner and intensity with which the accommodation process is carried out.

The process of accommodation, again because of the polarized nature of the hardened beliefs underlying it, begins even before a study is made. It extends through the study and lasts beyond the publication of the result. The study-subject and his co-workers act throughout in such a way as to protect their goals and interests with respect to a system they view as inimical to those interests. There are many ways, often subtle, in which this can be done: using non-optimal work methods, making an operation "look" difficult, withholding production, and so on.

The observer also acts throughout to protect his goals and interests, along with those he conceives to be management's; he is also constrained to act as though work measurement is, if not a matter of science, a matter of rational procedure, to be settled by experts. He has no difficulty finding ways of doing this, in particular, by judiciously rating worker performances in the process of discovering what a "normal worker" might do.

Given the beliefs and counter-beliefs involved, this is an entirely mute process carried on at arm's length. The result varies from a working equilibrium to resentful conflict, according to the particulars of a given situation. It should not occasion great surprise that the observers who insist most strongly that their results are scientific are also generally the ones who have most difficulty, in one form or another.

Putting this in summary form, the equilibrium achieved will, given conditions which apply quite well today in the United States, tend to favor the worker. This is because of two principal reasons. First, the worker usually knows far more than the observer does about his operation; hence, he can, given some subtlety, make invention seem like fact. Also, the worker (and his representatives) can decide on their follow-up accommodation strategy after they have inspected management's proposed standard. Management's insistence on exclusive prerogative to make studies thus reduces to a distinct liability because, in practice, management must commit itself before labor. Small wonder that trade unions have not crusaded too strenuously for labor's right to set production standards!

Another outcome of the work measurement process that bears examination is its long-term outcome. There is always an imbalance among production standards so that some are "looser" than others, that is, they are more favorable to the workers. This is a natural consequence of the fact that work measurement is not a science. That fact must be balanced, however, against the logical imperative that production standards be mutually consistent. To achieve this consistency, it usually becomes necessary to loosen the entire rate structure, usually in slow steps and perhaps even on a one-by-one basis.

There is here, as in so many things, a point of no return which, though not well marked, is quite definitive. When that point is reached there is no longer any need for going through the process of accommodation. Observations are still taken, to be sure, but largely for reasons of preserving form.

Any new production standards must be consistent with those already accepted. Thus if, as is usually the case, the old standards are loose, the new standards must be made loose from the beginning. (The writer knows of cases where even an hourglass would have shown a job could be done in X minutes, yet the production standard was knowingly set at 2X minutes.)

The final outcome in such cases—and there are many more than is generally supposed—is that the entire rate structure becomes loose. Since production standards are supposed to be considered one by one, again presumably because they are based on a science and would therefore *a priori* be mutually consistent, very little can be done about the situation.

Sometimes, as when the firm has a monopoly, nothing is done about such situations because the profit margin is still substantial. But, eventually, a problem always seems to arise, some times in the form of new enterprises attracted precisely because of the substantial profit margin. These enterprises can start out with more realistic production standards and, for this and other reasons, sell their product at sufficiently low prices that they give first firm stiff competition.

It is at this point that the parties usually begin to seek a remedy and they find that none is readily available. Production standards, it bears repeating, are supposed to be considered on an individual basis, not in terms of an integrated structure in which they bear consistent relations to one another.

This means that an attempt to develop more realistic standards would require that many operations be "restudied" and given new and tighter standards. Leaving aside the huge cost of making the studies, anyone familiar with labor in modern industry will attest that this would be accepted by workers only under desperate conditions.

What happened in a few cases the writer is familiar with is that the plant in question was moved into another and distant geographical area. There are other possibilities, of course, such as changes in technology or product. In any event, it seems clear that to resolve this problem, it must be attacked obliquely and in "purge" fashion.

The over-all situation is not nearly so bleak as this picture might indicate. The picture was intended to highlight the consequences of not understanding what might happen when processes of accommodation are not fully understood. It is one thing to understand there are such processes and quite another to follow them through their ultimate implications. Industrial Engineers who fail to do

this really fail to fully understand the meaning, usefulness, and limitations of their techniques.

THE OCCULT OF EFFICIENCY

Insights into what might well be done not only in work measurement, but in other areas of Industrial Engineering, can be obtained from a look at the field of job evaluation. One might well begin by recalling that, in Aldous Huxley's words, except for moderate doses efficiency is incompatible with the human spirit.

Unlike the field of work measurement, the field of job evaluation is rarely claimed to be scientific. Generally, the objective of job evaluation is stated to be a logical structure relating job content and wage rate, within which the various jobs have a consistent relation with one another. To be sure, there is in job analysis some of the characteristics one comes to expect from scientific measurement. But, by far the most prominent aspect of job evaluation is conceded to be just what its name implies, evaluation based on judgment.

There are a number of reasons why the claims made in job evaluation are more realistic than those made in work measurement. For one thing job evaluation attained prominence as recently as twenty-five years ago when the intellectual community was not nearly so insistent on the possibilities of scientific determinism. Then too measuring job content is not nearly so amenable to the claim of being scientific as measuring job time. There also is the fact that trade unions had by that time acquired both stature and bargaining strength; they would probably not have accepted techniques whose very mislabeling might lead to serious difficulties.

These facts show that the conditions under which a particular branch of Industrial Engineering is first introduced largely determine how the techniques are applied and what their consequences are. The openly evaluative nature of job evaluation has had a profound influence on the very definitions that go into its creeds, its statement of goals.

No one is unduly disturbed because job factors, for example, fall far short of being objective. This is not really damaging in practice, though it must be recorded that the imperative toward objectivity has led to far too many inquiries devoted to proving that job factors are not objective. These proofs, however, do not change practices very much so that the factors in use continue to be subjective, most often in the way originally conceived.

Not only is the lack of objectivity not damaging, but the lack of objectivity has decisive advantages. Foremost among these is that this permits (the definitions of) job factors to be permanent, and permanence is greatly to be desired in the definitions and creeds of any activity affecting human goals and interests. The same words can always be used to state what job factors are; their very subjectivity permits them to be adapted in practice to the particular needs of time and place.

Another advantage of subjectivity in job factors is that factors can be brought into play which really have little bearing on job content. Scholarly studies show, for example, that most job factors, such as degree of education, really don't have to be considered at all. Yet these factors are still given a standing in job evaluation, and one of the principal reasons is that recognition can be accorded to characteristics considered socially desirable, such again as degree of education.

Another advantage of subjectivity in job factors is that, if desired, a balance can be struck between jobs in different categories. Thus credit is granted for working under adverse and hazardous conditions, and credit is also granted for bringing to the job skill, ingenuity, and experience. But jobs involving adverse and hazardous conditions are rarely the ones requiring skill, ingenuity, and experience. The result is that job evaluation can be used to develop balances so as to prevent one type of job from having an overwhelming status and financial advantage over another.

Another advantage of subjectivity in job factors is that there must be a halo effect. Scholarly studies show, for example, that skill, ingenuity, experience, and education are ordinarily given highly correlated ratings, which is really what the halo effect means.

The existence of a halo effect grows out of the fact that job factors are not independent. This fact is accepted in job evaluation as a fact of technique, if not of life, and nothing much is done about it, assuming that something significant might be done about it. A similar fact exists in work measurement where operation subdivisions are not independent. There, however, this fact is buried under a mountain of mystical pronouncements together with an endless array of numbers. The intent of this seems to be the hope that a fact ceases to be a fact if we look at something else which is not. This, too can be traced back to the fiction that work measurement is a science.

Subjectivity in job factors is, of course, just one of the consequences flowing from the openly evaluative character of job evaluation. Other aspects of job evaluation have equally useful advantages for the same reasons and in essentially the same way. Summed up, they make possible an open and also subtle process of accommodation between the parties which can then adapt the results to their mutual advantage.

Since job evaluation is primarily evaluative, management generally makes no attempt to exclude labor from looking into the process, either in collaboration or by itself. Labor, in its turn, can adopt any role from interested observer to participant, according to its needs and goals. This open-endedness reduces the harshness and intensity of the accommodation process arising out of the diverse goals and interests of the parties. The frank and open atmosphere under which job evaluation is ordinarily conducted means that workers and their representatives often cooperate, at least in an informal way, in the evo-

lution of a job evaluation plan. This can be an advantage for both parties.

The objective of job evaluation, it will be recalled, is to develop a logical structure relating job content and wage rate, within which the various jobs have a consistent relation to one another. The accommodation process here is not a piecemeal process, with things considered one by one, as in the work measurement game. Rather, it is a process in which the entire job hierarchy is examined at once in open negotiation between the parties. The parties can, at one and the same time, see the total impact of the job evaluation program. They need not be caught in an entropy-like process over which eventually they no longer have control. This, too, can be of mutual advantage to the parties.

This is clearly not a complete story on job evaluation. There are problems here too, such as how to change the status of jobs when their job content changes. The point of immediate concern, however, is that job evaluation permits, in its modus operandi, a sufficient amount of slack for making accommodations so that a program can be worked out to the mutual advantage of the parties.

It is not appropriate here to draw direct and detail parallels between what happens in job evaluation and what happens in work measurement. The contrast between them has been sufficiently spelled out to establish a focal point: the value of providing slack for the making of accommodations within a rational framework, a framework which simply blocks out the relationships which seem warranted in the job hierarchy.

Perhaps it is desirable, in summing up, to refer back to the question of creeds and practices. In job evaluation the creeds, such as in the definition of job factors, are permament largely because they *do* lack objectivity; this really means they are not confused by the insertion of practical facts. That this can have desirable consequences has been pointed out.

In work measurement, on the other hand, the comparable definitions of the "normal worker," among other things, also lack objectivity. Yet they are not used as part of a creed serving as a formal and permanent base for making practical accommodations. Instead, and again because of the fiction that work measurement is scientific, large-scale programs are even now underway to make its concepts objective, such as that of the "normal worker."

The confusion, the difficulty, and even the vulgarization this must lead to has already been suggested. The task of making accommodations is rendered ever so much more difficult, and the task of accommodation is difficult from the beginning.

Top Management Decision and Simulation Processes

by **RICHARD BELLMAN**
The Rand Corporation, Santa Monica

I WOULD like to discuss simulation processes in general and a Top Management Decision Game in particular. The Top Management Decision Game is a kind of "do-it-yourself" kit for producing executives. It is hoped that this game will produce executives who are trustworthy, loyal, helpful, friendly, courteous, kind, obedient, cheerful, thrifty, brave, clean, and reverent. Furthermore, I am told that while playing the game, the players receive beneficial radiation, and that the very pencils they chew are impregnated with vitamins.

The first question that should be asked is: Why are people interested these days in management training programs, and why do we have simulation processes?

REASONS FOR SIMULATION PROCESSES

Probably the principal reason we do have simulation processes is that various organizations are willing to pay for them—and pay fairly good prices. After all, there is a law of supply and demand in the scientific world as well as elsewhere. Naturally, the next question is: Why are people willing to pay fancy prices for the construction of these games and for the privilege of participating in them?

The answer is obvious—there must be problems around of some import that cannot be solved readily and quickly. The majority of people in responsible positions, company presidents, generals and admirals in high military positions, are convinced that the problems that face us in economic and military life are that level of complexity and significance that they warrant sustained research. They require a great deal of thought and a great deal of effort by individuals of high intellectual level. Since these problems are so difficult, it is recognized that we must start now if we wish to obtain results five and even ten years from now.

In view of the foregoing remarks, it is natural to ask why these problems are so difficult. An easy answer is that they are complicated. We face processes involving a large number of interactions, an enormous number of factors, and a bewildering variety of decisions.

The enterprising company president facing this situation decides to buy a giant computer. He has read of what these electronic brains can do, how they are able to perform fantastic calculations calling upon storage facilities for hundreds and thousands of bits of information. What can be simpler and more progressive than to purchase this tame monster and solve problems in this fashion?

The company president buys one of the biggest and fastest machines, turns to his planners and programmers, presents them with charts crammed full with data, and says: "Solve the following problems for me; put 'em on the machine!"

At this, the programmer and the planner are apt to become a bit indignant. "After all," they say, "we know that these machines are fantastic devices. But they are not thinking machines—someone has to tell them what to do."

Now, of course, this may not jibe with what you may have read in the Sunday supplements and in some of the over-enthusiastic publicity that occasionally appears. One somehow gets the impression from these sources that computing machines solve their own problems.

The general impression that one gets is that of a room, tastefully decorated, with a big machine at one end flashing lights and a little table at the other end. One enters, places a problem on the table and tiptoes out. The next morning one finds, in the very same place, the solution, typed out and bound in quiet Morocco.

Fortunately for mathematicians, but unfortunately for executives, things don't work that way.

After all this has been explained, the company president generally says, perhaps reluctantly, "OK, let's hire some mathematicians. If we can't solve the problem by ourselves, let the mathematicians solve it."

The mathematician gravely surveys the problem and he says, "This is a very unsatisfactory type of problem as far as the mathematician is concerned, for the following reasons. In the engineering world, we face precise problems. We may wish to construct a space-ship to go to Mars or Venus; we may wish to construct a multi-stage missile. The question is that of constructing a device that will attain a given velocity, carry an assigned payload, and be able to penetrate hundreds of thousands or hundreds of millions of miles into space—a clear-cut problem.

LEARNING THE OBJECTIVE

Whatever the engineering, physical or mathematical obstacles, we can clearly state our objective.

When we turn to the military and business end of the world, we find to our great surprise that we frequently cannot say exactly what we want to do. Since this is a rather startling statement, let us examine it a bit in order to help you believe it. Consider the following sample example. We aproach a business man and we ask: "What are you trying to do? What is your objective in running your firm?" Generally, he will answer, "I am trying to make money." At which point we reply, "Are you interested in maximizing the amount of money that you will make this year?" And he will answer: "Well, certainly, I want to maximize the profit over the coming year."

At this, we point out that this isn't all he wants to do. Otherwise, he would sell the business, lock, stock and barrel, and over a period of one year show an enormous profit. Naturally, this idea is rejected—he does want to stay in business. In other words, not only must he worry about the immediate revenue over the coming year, but he must take into account the continuation.

If we press further and ask how he knows whether or not he is in a favorable position, and how he evaluates his business, he will talk about share of the market, new products, efficiency, unit cost, and easily a half-dozen other factors.

After listening patiently, we may say: "Here are the six or a dozen factors that you mentioned. Please write down a precise formula which tells me how you evaluate these factors. Which are the most important, and how do you weight one against the other?"

As soon as we ask a specific question of this type, there is silence. Since we have great faith in experts, the temptation is to turn to an expert and ask him for the answer to these questions. We find to our dismay that there are no precise answers.

Consequently, the very first difficulty that we encounter in trying to tackle some of the formidable problems of the economic and military world, and in trying to tackle them by means of scientific techniques, is that we cannot even state the problems clearly.

After a certain amount of sadness, and self-pity, we decide to introduce artificial but reasonable criteria. Suppose for the moment that we measure success in terms of the amount of money made over ten years, suitably discounted.

Having successfully dodged the difficulty of evaluation, the next type of question that arises in our attempt to apply mathematical methods is: "What happens when a decision is made?"

Suppose, for example, that we decide that a conservative, old-line firm needs some pepping-up in the form of an advertising campaign. Should one spend a quarter of a million dollars, half a million dollars or a million dollars, and how do these expenditures on TV, Radio or Magazine advertising affect sales?

Once again we think of turning to experts, advertising experts in this case. We know, of course, that actually there isn't any one who can furnish this information.

Consequently, at this point the mathematician again complains. How can one use mathematical techniques if there are no formulas? The temptation is to classify these problems as impossible. We don't know the precise result of a decision, and we don't even know precisely why we

want to make these decisions.

For some mathematicians there is a very easy way out of this irritating situation. They turn to other fields.

Unfortunately, the intelligent person who is concerned with these matters cannot avail himself of this simple refuge. He knows from past experience that if the person of ability sidesteps his responsibilities, if he retreats from these problems as too difficult, there is always someone else around with complete faith in his own ability to resolve these questions.

The problem the mathematician must face is the following: Using all his mathematical ability, using all the techniques of modern computers, can he do something in this field which is better than what can be done by an executive with only business experience to guide him? In general, the answer would be—no! If we have a choice of two experts, one a mathematician with digital computers, the other an executive with thirty years of experience, we would certainly rely upon the business man to make an important decision.

In view of the fact that we cannot hope for an analytic solution, is there some way we can bypass the cost in time required for experience? Is there some method for speeding up the process of acquiring experience? With this thought in mind, let us turn to the idea of a simulation process.

THE SIMULATION PROCESS

A simulation process is a quite obvious engineering idea. It is the concept of the pilot plant, the towing tank and the wind tunnel—a simple and yet fundamental idea.

We say: If we cannot analyze a process in purely mathematical fashion, scientifically according to simple principles and formulas thereby deduced, at very least what we can do is watch it. We will watch the process, observe what happens, and in that way learn what to do.

However, as I have just pointed out, in the business world it appears that one has to watch for quite a long while—ten years, twenty years, thirty years. In other words, in treating really important processes we must realize that the only totally realistic model of the process is the process itself.

It follows that in studying many of the significant problems of the business and military world we cannot use this simple engineering technique in any naive fashion. It is not sufficient to say that we shall merely watch and wait.

We are forced back to the use of mathematical and scientific techniques—unconventional, and perhaps more sophisticated in some ways, but still scientific techniques. The use of simulation techniques represents the application of standard scientific methods to areas which have not previously been treated to any extent by scientific techniques. These areas are particularly those in the economic and military spheres.

To take a particular example, consider the problem of running a multi-million dollar organization. We attempt to abstract certain basic features and use these to construct a small-scale model. It is hoped then that something can be learned from these models.

Model-making is an art, and quite a complicated one. It is complicated even in the physical world where we have had several hundred years of experience. Hence, it is even more complicated in fields in which only recently have scientific techniques been introduced. Our aim is to study at any particular time a small number of the factors that influence decision-making and to try and determine the effects of various types of policies.

Running these processes, which we call simulation processes, over and over under varying conditions, we hope to build up synthetic experience.

All of this is quite vague, and quite difficult. In attempting to construct a simulation process, we are faced by the question of pinpointing factors of importance. Also we must describe the effects of the various possible decisions.

We thus seem to be right back facing the problems that discouraged us initially. How do we single out important factors and how do we evaluate policies.

What saves us from despair is the knowledge that there do exist people who perform these complicated decision-making roles in outstanding fashion. There are successful executives and there are successful generals. Consequently, there must be ways of overcoming these difficulties to some extent.

In order to see how this may be done, let us examine the idea of the scientific method. One method that has been enormously successful is what we may call the syllogistic approach, the usual logical algorithm.

Starting with a fact "A," we observe that "A" implies "B," "B" implies "C," and "C" implies "D." Consequently, when "A" occurs, we make a decision based upon "D." This has been such a successful method in many fields, that we tend to think that it is the only method that can be used.

Actually, it is not the way that most of us come to conclusions. If you consider any of the significant processes of life, you soon realize that there is never enough known to make successful deductions of the type described above.

What we do when forced to make a decision is to search our memories and try to recall a similar situation. If we can do this and remember certain decisions which were successful, and other which were unsuccessful, we possess valuable clues as to further successful behavior. What we are calling upon is experience, memory of past similar situations.

The idea we wish to stress is that in most situations we perceive more by analogy than by deduction.

Processes that seem to reveal this quite well are those of chess and poker. We all know that there are good chess players and good poker players. To hear some, however,

it would appear that there are merely lucky and unlucky players. It is next to impossible to get a consistent loser to admit that his play is defective. On the other hand, these players are beloved by their friends and there is always room for them around the table.

Let us turn to the game of chess. Attempting to analyze chess scientifically, we see that we require a means of evaluating a given position. We need an expert who can look at a particular position and evaluate it as a winning or losing position. What is desired is a formula which will take account of the positions of all the pieces and come out with a yes or no answer—a win or a loss.

Fortunately for the game of chess, nobody has yet been able to do this. Examine the most profound studies of the greatest chess players and you find that they cannot tell why it is that they play excellent chess. They can furnish all kinds of sound strategic principles, and these are of great help. But they have no means of formalizing exactly what they do.

TRAINING PROCESSES

If we insist upon asking for the *best* way to proceed, we may get into difficulties. This is mainly due to the fact that we don't know what we mean by "best." If, however, we agree to try to construct various training processes which will teach people how to proceed in reasonably good fashion in situations of the type described above, then it is quite plausible that something can be done.

The game of poker is an excellent example of this general premise. Here is a game which lends itself to mathematical analysis to a slightly better degree than the highly complex decision processes we have been discussing. Nonetheless, there is no theory which predicts exactly how to play optimally in a five or seven-handed game. However, using native intelligence and experience, one can become a competent, if not gifted, player.

MANAGEMENT TRAINING GAME

Aware of the difficulties that I mentioned above, and aware also of some of the compensating factors, about two years ago five hardy souls got together to consider the problem of constructing a simulation process that might be useful in training executives. The purpose of this simulation would be to furnish the synthetic experience that would cut down on the usual time required for training.

These five were Don Malcolm and an assistant, Charles Clark, from Booz, Allen and Hamilton, Franc Ricciardi and an assistant, Cliff Craft, from the American Management Association, and the author, from the RAND Corporation.

Since construction of games of this general nature had been tried before, we did have the benefit of the mistakes of others. Taking advantage of this experience, we felt that we could construct a workable game if we kept everything fairly simple. We didn't have to be very bright; all we had to do was to avoid the mistakes of predecessors. This was part of it; it turned out that the problem was more complex than imagined. In order to conquer all the difficulties, to some extent, we also had to be lucky. I will explain in a moment why it was that we needed luck.

I would like to emphasize that in complex research programs of this type, mistakes cannot be avoided. Upon first traveling down a road, all bypaths look equally inviting. Only upon having traversed it a few times do we begin to recognize certain of these as dead-ends and others as through-ways.

At the very beginning, we thought that it might be feasible to copy the type of war game that the military forces have utilized for some time. These involve vast quantities of men and equipment. A little thought showed that this was certainly unworkable in a business game.

One of the reasons that the armed forces can engage in vast scale maneuvers is because to a great extent, each of the participant groups follows preassigned patterns.

In the construction of our game, we had to take into account a number of serious constraints on time, expense and complication. Since we were thinking of processes of some degree of realism and magnitude, it was clear from the beginning that we would have to think in terms of digital computers. It is rather surprising that the capacity of a computer is one of the limiting factors in the construction of a simulation process.

In view of this, and in view of the fact that processes that overwhelmed a computer might very well do likewise to the players, we decided to construct a fairly simple-minded game. Only one product would be manufactured and sold, to the tune of a few simple decisions, namely: How much should we produce? Should we build more plant capacity to increase production? Should we spend money on research and development, and on advertising? What price should we charge? These were the basic questions.

PROBLEMS OF THE GAME

The first problem that faced us was: If this was to be a game, how could we tell the players whether they were winning or losing? In bridge, football, chess, or tiddlywinks, we have simple criteria for winning or losing. But in the economic and military spheres, no such simple criteria exist, except perhaps at the very end of the process.

After the equivalent of five or seven years of play, there will be some indication of a trend. It would, however, be nice to know before that time. As I pointed out before, this is a fundamental problem and there is no simple way around it.

Fortunately, we can sidestep it in a very simple fashion—we refuse to tell the players whether they are winning or losing. Instead, we say: "You're a business man, you evaluate the situation. Use the experience you have

had in the business world, and act exactly as you would in a realistic situation."

This, of course, puts the burden of the problem upon the players and upon the construction of the game. The simulation has to be accurate enough so that people will take it seriously and the players must be mature enough so that they will not try outlandish strategies. They must be people who are interested in testing serious policies.

We have had considerable success in both respects. We have found that the game has been realistic enough to attract attention and interest, and we have been fortunate in obtaining a considerable number of serious players.

One of the most gratifying features, from the professional point of view, has been that the business men consistently beat the mathematicians. This is, of course, the way it should be. If the game is to pretend to realism, it must be true that the person who has had experience in the business world should be able to use this experience to do far better than someone like myself who is merely familiar with all the formulas that go into the game.

I say this with a certain amount of bitterness, because I would have liked to have won. Although I have always had excellent theories, somehow the other players have never been as cooperative as they could be. The result has been that I have never done well, and thus have been forced to console myself with the thought that this is an excellent indication of the realism of the process.

Having passed the criterion hurdle, with a certain amount of agonizing soul-searching, we came to the problem of determining cause and effect. As I have remarked above, we don't know what happens when advertising is increased, or prices are lowered. On the other hand, we must give a digital computer specific instructions. We cannot ask it to use its discretion.

It is necessary to have specific formulas which tell how our share of the market has changed as a consequence of our decisions, and the decisions of our competitors.

We decided that the simplest thing to do, from our standpoint of research and training, would be to choose some reasonable functions with the correct qualitative behavior. If the price was increased, sales decreased and vice versa. But we didn't tell the players what these formulas were. Again our defense was that in any realistic situation these formulas are not known—and may not even exist. Our excuse for ignorance in all these cases is the same: "After all, this is the way things are on the outside."

There still remained a number of other problems. We wanted the game to be flexible, which is to say we wanted definite reactions to changes in policy. On the other hand, we did not wish too strong a reaction, which is to say, we wanted stability.

It is not desirable to have a change of price of say 25¢ on a $5.00 item result in cornering the market and reducing the other players to bankruptcy.

In addition, there was a quite compelling reason for making sure that no crises occurred. The American Management Association is using this business game as part of an intensive course in decision-making. Clearly, if the players are charged approximately one thousand dollars for a two weeks course, it is not desirable to have anyone go bankrupt in two days. At first, we actually thought that it was impossible for this to happen if any reasonable policy was pursued. However, we made the mistake of putting two comptrollers together. Now without any personal prejudice against comptrollers, apart from their peculiar fancy of wanting everything in triplicate, I think that it is fair to say that the philosophy of these gentlemen may be expressed as follows: "Whenever you think of spending a dollar, don't."

The result is that this team resolutely refused to spend any money on advertising, any money on research and development, any money on anything at all. The result was that after two or three rounds, they went bankrupt. Since this was a demonstration game, with the machine programmed for a full five teams, we had to slip them money surreptitiously to keep them in the game.

Forewarned by this, we put in some further magic formulas which absolutely prevent bankruptcy. A team pursuing a foolish policy will not do well, but it will exist.

As I pointed out above, we wanted a flexible game, which is to say we wished to observe an appreciable change when there was a change in policy. Yet we did not want it to be too flexible, to have any violent ups and downs. Consequently, we were faced with a very delicate problem of balancing the interactions. In order to do this, we indulged in a considerable amount of experimentation, playing various stages of the game ourselves.

Members of the group were appointed devil's advocates. One would be chosen to follow a high price, no advertising policy, another a low price, extensive advertising policy, and so on. Occasionally, the person nominated would protest bitterly that his assigned policy did not coincide with his own ideas. No matter, it was necessary to try all extreme policies. As a matter of fact, when first setting up the game, we found that quite a few safeguards had been omitted. The result was occasionally a policy of raising the price from five dollars to ten dollars would corner all the money in the game. This is one of the most serious problems encountered in constructing mathematical models. In any realistic situation, there are built-in properties which automatically eliminate absurd policies. Sometimes, in making a model of an economic situation, we attempt to eliminate what appear to be small effects, and find that precisely these small effects play a determining role in certain processes.

We find then that obviously foolish policies, foolish from the standpoint of actual practice, do very well in artificial games. We call these policies "gimmick poli-

cies." In constructing a simulation process, we want to make sure that no artificial policies, known only to the constructors of the game, will dominate sensible policies.

This is where luck entered. We were remarkably fortunate in the relatively short time that we devoted to the construction of the game to come up with choices of functions and parameters which yielded a reasonably sensitive and reasonably stable game.

Having reached this stage, we decided to try it out first on vice presidential level executives, and then, in May of 1957, on a selected group of presidents of large companies. The enthusiasm generated by this demonstration was so great that the American Management Association decided to invest a great deal of money and effort upon a management decision course built around the game. This was started at the end of last year, and appears to have met with success.

PURPOSE OF THE GAME

I would like to discuss briefly in conclusion what I feel the real purpose of the game is, and how it can be used most profitably. At the present time, no responsible individual claims that games of this type can be used to resolve actual industrial problems. We constantly warn the players that the situations in the game are make-believe situations, and thus not to be taken too seriously. If research and development pays off well, it is not to be concluded that the answer to any realistic problem is more research and development. After all, since those of us who designed the game were partially or wholly in the Operations Research racket, it is clear why we would want to emphasize this feature. We were using subliminal perception, without the aid of a movie screen.

Amusingly enough, one of the engineering magazines rather unethically told its readers how to beat the game. Actually, the policy the magazine advocated was quite wrong, since it was based upon an observation of only about one-fourth of the whole process.

SIMULATION—A RESEARCH TOOL

We make no pretense that this simulation process is an operational tool at the present time. Rather, we stress that it is a research tool. Research was for a while quite a dirty word, but it has become more popular in recent times with the aid of Sputnik. One can now assert in public, without wincing or apologizing, that one is engaging in research.

Apart from the type of training we have mentioned above, how can this research tool be used in a most profitable way? In the first place, I think that it should be used in the universities to a tremendous extent. One of the aspects of human nature, which the universities have refused to cater to, is the gambling instinct. This is not surprising, considering that what used to be called progressive education refused even to admit to the existence of the competitive instinct. Yet, whether we like it or not, it is clear from a study of all civilizations on the surface of the earth, going back to the ancient Egyptian and Sumerian tombs, that humans love to gamble. In these tombs of five and six thousand years ago, one finds dice and board games of all types, ancient predecessors of chess and checkers.

It would seem to me that games of this type introduced into courses in business administration, mathematical economics, operations research, and many other subjects, would stimulate the students to a considerable degree. At the present time, a number of games modeled after the AMA game are being used in various universities around the country.

Secondly, I think that games of this type can be used as super intelligence tests. At the present time, intelligence tests, although given widely, are not taken too seriously. One of the reasons for this, it is generally agreed, is that what we call an intelligence test is actually a measure of only a few of the facets of human intelligence.

One of the basic aspects of human intelligence, and animal intelligence as well, is the ability to adapt to environment, and particularly to changing environment. In other words, intelligence should be tested in terms not of what one knows, but of what one can learn.

It is clear that no static test can measure this feature of intelligence. We need a dynamic process, precisely of the general nature of the simulation process described above. Although there is little doubt that processes of the foregoing type can be used for these purposes, much remains to be done before they can be used for quantitative purposes. It is not as easy as one might think to determine what it is that is being measured and to what extent.

I do believe that these simulation techniques will assume a greater and greater role in the future, and eventually become operational tools. The appropriate story on which to close is the following.

A stranger who loved to gamble came into a little town and inquired about the possibility of some action. He was directed to the back room of a local saloon where there was a roulette wheel. A kindhearted townsman pointed out, however, that the wheel was crooked. The stranger shrugged his shoulders and said, "I know, but it's the only wheel in town."

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President's Message

GEORGE H. GUSTAT

President, American Institute of Industrial Engineers, Inc.

1958-59

Professional Relations

ENGINEERS of all specialities generally regard themselves as members of a professional group. The unbiased public has accepted this status in a large number of individual instances where the person concerned merited the recognition; however, the behavior of the bulk of engineers, as individuals, has been found wanting in those very characteristics that distinguish the professional from the layman. A professional man incurs a number of responsibilities to society that he cannot ignore except at the risk of losing his professional status. Professional recognition is not automatically conferred upon graduation nor does it accrue with the mere passing of time. It is merited by individual behavior, and when a sufficiently large number of people practicing the same arts or the same sciences hold to a criterion that puts service to mankind above all other things, then a professional group comes into existence.

This may appear to be a paradox: by definition, we exist to serve mankind—the profession of engineering is described as the application of science in adapting materials found in nature into a form more useful to mankind and the harnessing or controlling of natural forces to do man's work. A narrow interpretation would limit the engineer to only the technical problems concerned, but why should we have this narrow viewpoint when we have been trained to think in terms of the whole problem. The technological changes introduced by the engineer, even though initially designed to better our standard of living, have created social, economic, and even international disruptions in the habits and customs of society in general.

Therefore, the whole problem encompasses the effect of our work upon mankind, and we can not ignore the reactions of society to our efforts. As Industrial Engineers we are, if anything, even more closely concerned with the human factor, since the integration of men, materials, and equipment of any system is our field of specialization. Nearly every phase of Industrial Engineering activity involves people.

A considerable amount of lip-service is given in recognizing the responsibility that we have here, but a man is rightly judged by what he does rather than by what he says, and you and I both know that not too much of our time is spent in civic or community affairs at the local level. Only a start is being made with social and economic problems at the national level.

Since we are members of the engineering profession, we have no choice but to broaden and develop those activities that will continue to identify the aim of the American Institute of Industrial Engineers in regard to Professional Development as being the same as that of other professional engineering groups. This means meeting and working with not only other engineering societies, but with engineering educators and with the general public

on matters of civic and community interest. In fact, one index or measure of our professional status is the degree in which we are successful in coordinating with these groups on the local and national scene.

There are some who think we should work independently—that as Industrial Engineers we do not have that much in common with other engineers. I would like to remind this group of just some of the things that we share in common with other engineers that in themselves make continued coordination and unity of purpose a desirable pattern of behavior:

1. We have a common heritage. We are at the same time a product of, and creators of our modern culture. As a formal group with a definite set of requirements, the oldest of us has been around perhaps 130 years. We are young—engineering did not begin to emerge as a science until the eighteenth century. Recalling that written records go back about 5000 years, this is not a very long period of time. As a profession we share a common trait of youthfulness and the growing pains that other professionals had to bear.
2. All engineering has its roots in the pure sciences and abstract thought. During the first two years of a four year program the subjects taught at the undergraduate level are the same: Physics, Chemistry, Mathematics and Engineering Drawing. We find that continual changes in engineering curricula in the last two years are normal. For example, the Electrical Engineers have traditionally made the most sustained use of the higher forms of mathematics. Today Industrial Engineers in industry are finding it necessary to attend evening courses, company sponsored training courses, and seminars in mathematics and statistical techniques in order to gain more background in these subjects than is normally covered at the undergraduate level. The emphasis on symbolic logic in the current literature does not necessarily mean we should be mathematicians first and engineers second no more than it did for the Electrical Engineer.

   The general aim for engineering educators is the same for all branches of engineering—the accumulation, testing and application of scientific data. It is not at all uncommon today for an engineering graduate to have been exposed to courses in fields of engineering other than his own. In fact, many go on to successful careers in fields other than the one in which they received their degree. In many other instances engineers in different fields of specialization work closely together as a team. This pattern of cooperation marks the engineering profession as a whole.
3. We share a common general definition: "An engineer has been defined as a person with extensive knowledge of some area of technological science—knowledge which is formal and abstract rather than purely empirical." This extensive knowledge or technical proficiency, I would like to repeat, does not define the total area of professional development.
4. The professional engineering societies vary somewhat in their membership requirements. However, currently they have either accepted in substance or are approaching the standards proposed by the committee on Professional Recognition of the Engineers Council for Professional Development: "A member should be a graduate of an approved engineering curricula plus at least four years of increasingly important engineering experience or at least ten years of increasingly important engineering experience."
5. A number of other items can be grouped as areas of common interest to all engineers:
   a. The continual education of engineers: This is a vital part of professional development regardless of speciality. A program for self improvement should be the result of a joint effort on the part of the new engineer and the experienced professional.
   b. The question of professional status.
   c. Antipathy towards professional activities: The small percentage of engineers taking part in professional societies reflects this weakness.
6. Every engineer regardless of his field of specialization is a representative of the engineering profession in the eyes of the general public. What each of us does and says as an individual reflects on the engineering profession as a whole.

We have an inherent interest, therefore, in just about everything that affects the engineering profession. To implement this interest at a national level AIIE has already accomplished several things:

1. We have been accepted as constitutent members of the Engineers Joint Council—a group representing one quarter of a million engineers. Under the capable leadership of Dr. Alex Rathe, Chairman of the Professional Relations Committee, we will be actively participating on 17 different committees of this council.

   For the second year we were active on the Nuclear Congress Committee, the Committee on International Relations, and the Engineering Manpower Commission. We are also active on the Practice of Engineering Committee, The Program Committee (involving joint planning with the Council for Professional Development) and the Board of Directors for the Engineers Joint Council. This coming year will see Industrial Engineers in the following groups:
   a. The Committee of Secretaries
   b. The Committee of Editors
   c. The Finance Committee
   d. Membership Committee
   e. Planning Committee
   f. The National Engineers Register
   g. Employment Conditions Committee
   h. Recognition of Specialities Committee
   i. Engineering Services Committee
   j. Who's Who in Engineering Committee
   k. The Insigne Committee

   I think it is significant that of all the worthwhile projects undertaken by the Engineers Joint Council, Dr. Rathe and many others consider unity within the profession to be the most important problem before the Engineers Joint Council.
2. We have been invited by the Founders Societies to joint sponsorship of future Engineering Management Conferences. In the acceptance of this invitation the American Institute of Industrial Engineers made two points:
   a. "The field of Engineering Management is properly viewed as an area of common interest to all engineers, however, Management Engineering remains within the province of the American Institute of Industrial Engineers."
   b. "Any future invitations to still other societies for cosponsorship should be restricted to organizations with membership qualifications which compare favorably with those of the present six groups."
3. The American Institute of Industrial Engineers is not a member of the Engineers' Council for Professional Development. However, we have been invited to participate in two of its major activities.
   a. The accreditation of Industrial Engineering College Curricula.
   b. The Professional Development of the Young Graduate.

As engineers, our tap roots are as deeply imbedded in the historical development of the engineering profession

as those of any other field of engineering; but as an organized body the American Institute of Industrial Engineers is the youngest member of the engineering organizations. We are vulnerable to problems that the older organizations have, in many cases, already resolved. There is much we can learn from them. Not the least of our concerns is living down the ill-repute generated between World War I and II by a group of non-professionals whose ethics today we would never condone.

As some of you may recall, immediately after World War I the industrial economy in this country shifted from production of military goods to peace time needs. The removal of the common bond that had welded labor and management together during the national emergency was partially responsible for some of the industrial unrest during the twenties. Into this troubled scene stumbled or crawled a group of eager exploiters who collectively so thoroughly blackened the name of Industrial Engineering that reactionary effects are still with us a quarter of a century later. This, as K. Theodore Korn has written, was the period of commercialization of Industrial Engineering. This shameful prostitution of our science dragged Industrial Engineering to the levels of hucksters and con men. The era of the "Efficiency Expert" described by Mr. Korn in the "Manhood of Industrial Engineering" should be "must" reading for all new Industrial Engineers. The chemists have had, in their time, to contend with the alchemist; the medical profession has had its barbers, and we had the "Efficiency Expert."

The day of infamy is past, but an aggressive vigilance will be required to make sure it will never dawn again. This vigilance is your individual responsibility, not that of some mythical group. It is our responsibility as individuals to let the public know us for what we really are. To accomplish this, one of the things we must do is participate at a local level in civic and community affairs. Participation of this kind, as viewed by the public in general, is an index of our value to society. No community is so small or so large that our services would not be required or valued. Many of our chapters have already joined other professional engineering groups in order to coordinate and unify engineering activities at the local level. As a result hospitals have received services otherwise unavailable or costly to them, Career Days have been inaugurated at high schools, and assistance provided to centers for the rehabilitation of handicapped people. It is in these directions that we should expand our activities. Other engineering organizations have taken the lead in developing this responsibility. We belong with the leaders.

The sense of professionalism of the typical engineer leaves much to be desired. He does not naturally incline towards the activities of professional societies. He doesn't see the need and does not view participation as a status builder. If individual engineers wish to establish themselves as members of a professional group they obviously need to give more of their time and effort to the activities that are characteristic of professional people.

By way of self analysis here are some questions to ask yourself:

1. What contributions am I personally making to expand the activities of my local chapter?
2. What steps have I taken to coordinate with other engineering groups in my areas on matters dealing with:
   a. Aid to educational institutions in modifying and developing curricula?
   b. Aid to high schools and college students?
   c. Development to post graduate courses?
   d. Joint meetings with other professionals on common topics?
   e. Professional assistance to local social and welfare agencies and governing bodies?
3. What am I doing to broaden my own technological and cultural interests?
4. What activities do I participate in that allow me to lend my knowledge and experience to the betterment of society in general?

As you mull over these questions you should be neither discouraged nor satisfied. If you find yourself wanting in professional growth you can start at once to do something about it. If you don't, 5, 10 or 15 years from now you will be still further behind.

If on the other hand you feel a little on the satisfied side about your own participation and activities, then bear in mind that it is to people such as yourself that the others must turn to for guidance and assistance. This means that your contributions must of necessity be still greater. This is the burden that leaders have always had to carry.

Engineers have been accepted as members of a professional group through the efforts of those who have accepted and carried out the responsibilities of the true professional. Continued professional recognition and growth will not come as a result of legislation nor can we always expect to depend on a select few to carry the burden. Each one of us must accept the responsibilities of being a professional man.

The engineering profession has received its full share of blame, some of it perhaps justified, for some of the inevitable social problems resulting from technological advances. The anthropologist, the social psychologists, the sociologists, and the economists have all been concerned with the problems generated through the human inter-actions, the group reactions, and the cultural changes stemming from engineering accomplishments. As engineers, we can not concern ourselves solely with the inanimate aspects of our work without being inconsistent with the very fundamental reason for our professional existence—to serve mankind.

If our breadth of vision is greater than that of our predecessors, it is because we stand upon the shoulders of their experience. Let us provide a firm foundation for those that follow us, so that this growth will continue and our professional status will be assured.

American Institute of Industrial Engineers, Inc.
145 N. High St.
Columbus 15, Ohio

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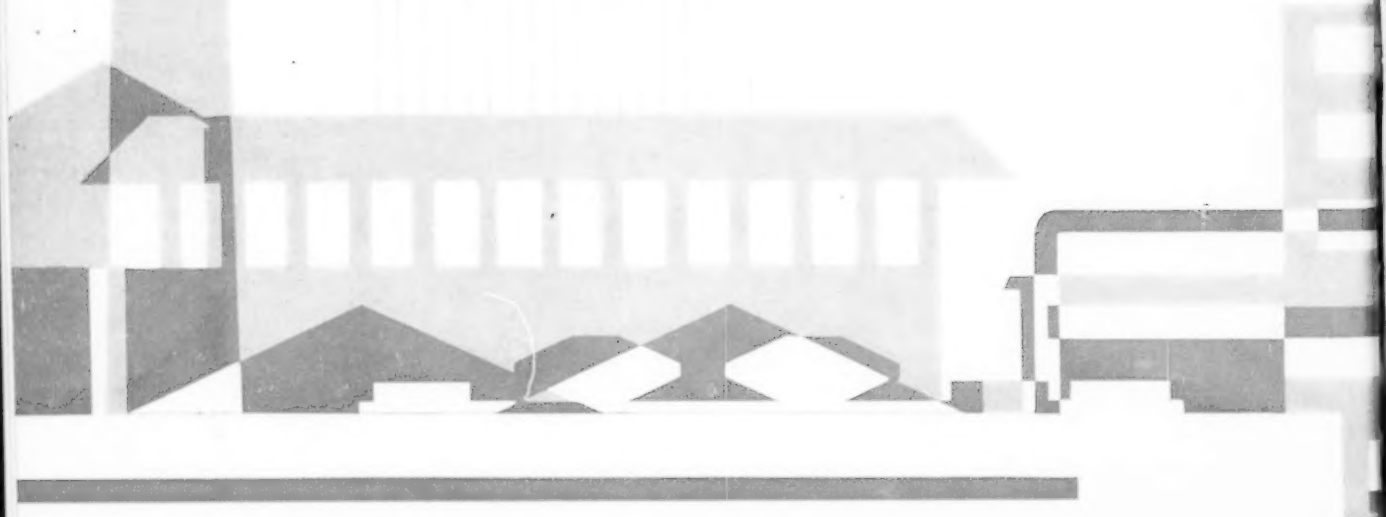
Industrial Engineering **is concerned with the design, improvement, and installation of integrated systems of men, materials and equipment; drawing upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems.**